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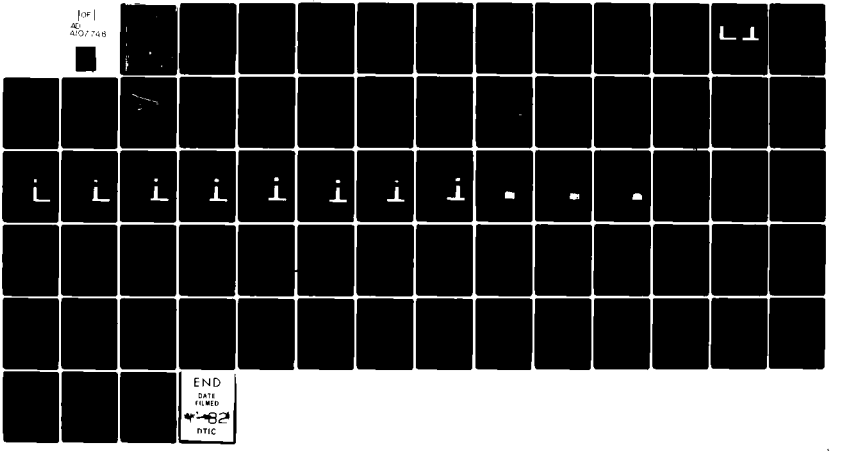

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Transition to Double Mach Stem for Nuclear Explosion at 104 Ft Height of Burst

M. Fry

Science Applications, Inc.
McLean, VA 22102

J. M. Picone, J. P. Boris, and D. L. Book

Laboratory for Computational Physics

November 17, 1981

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A nuclear height-of-burst (HOB) calculation has been performed using a two-dimensional flux-corrected transport (FCT) code. The calculation predicts the transition from regular to Mach reflection at ground ranges approximately equal to the HOB. The characteristics of the resulting waveforms are basically the same as those found in shock tube experiments when planar shocks reflect from wedges, and appear highly regular. In the double-Mach reflection region the first Mach stem is observed to toe out markedly compared with the planar case. In the high-over-pressure (regular reflection) region initialization errors and inadequate resolution caused pressure peaks to appear too low by about 20%. In the Mach reflection region the peak pressures are in good agreement with experimental data.

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CONTENTS

TRANSITION TO DOUBLE MACH STEM FOR NUCLEAR EXPLOSION AT 104 FT HEIGHT OF BURST

I. INTRODUCTION

In a nuclear height-of-burst (HOB) detonation the spherical blast wave reflects from the ground, initially producing a regular reflection region. When the shock reaches a ground range approximately equal to the HOB an abrupt transition to Mach reflection occurs. This transition is responsible for an airblast environment more severe than the surface burst nuclear case. Qualitatively, it can be thought of as a partial flow stagnation in the Mach region that leads to the production of two static pressure peaks.

A 1 Kiloton (1 KT) atmospheric nuclear explosion at a HOB of 104 feet has been simulated using the two dimensional FAST2D code (Ref .1). Figure 1 illustrates the shock structure. The calculation predicts the transition of the shock from regular reflection to double Mach reflection. Because the spherical waves are expanding and thus decreasing in Mach number as well as angle of incidence with the ground, they create a dynamic Mach stem formation. In comparision to planar shocks on wedges one finds them to be qualitatively alike. The appearance of double peaks in the pressure and density profiles (versus time and distance) is interpreted as the point of transition. Other interesting phenomena such as the rollup of the contact surface generating a vortex ring and the associated phenomenon of toeing out of the first Mach stem can be observed.

The ability of the calculation to accurately predict the gasdynamic effects both temporally and spatially is due in part to the shock capturing and adaptive rezone features of the FAST2D code. A minimal number of very fine zones was placed around the shock front and these zones then moved with the first Mach stem to prevent shock smearing and distortion. This calculation is the first attempt to model the nuclear HOB case through the use of a Flux-Corrected Transport (FCT) algorithm (Ref. 2).

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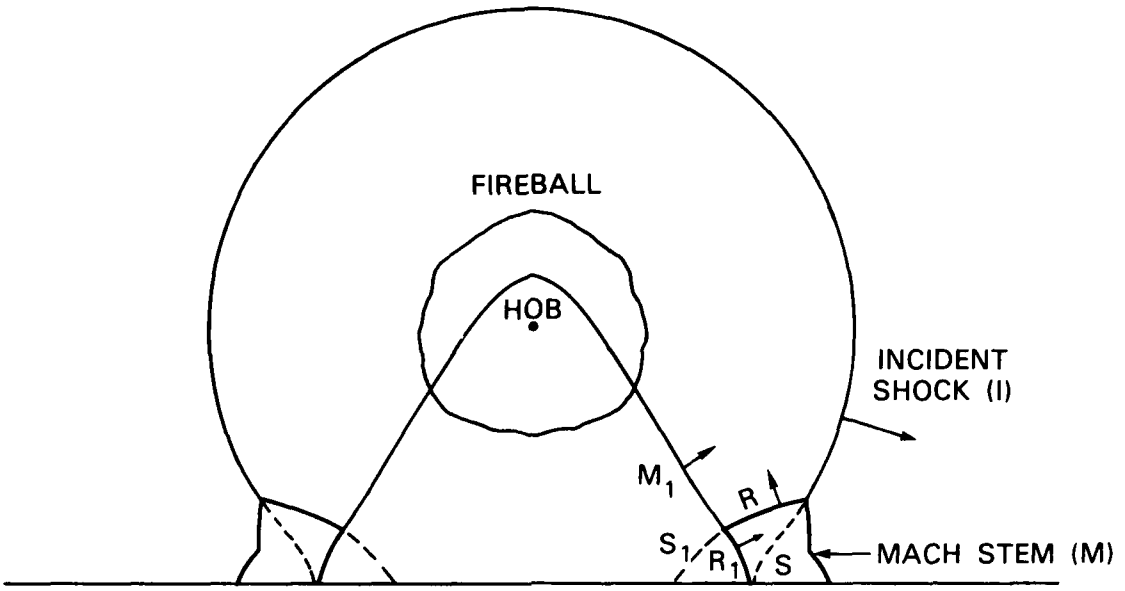

Fig. 1 - Mach stem structure from HOB

The results of this calculation agree well with the pressure-distance curve generated by the high explosive (HE) data of Carpenter (Ref. 3) and the analysis of Kuhl (Ref. 4). The peak overpressure of the first shock at the time of transition is about 4300 psi. Our simulation was run to 11.6 ms (total time with t_o = 3.76 ms), which corresponds to pressure peaks of about 2000 psi. In the regular reflection region the peak values tend to be about 20% low due to the clipping of the FCT algorithm and inaccuracies in the initialization of the flow. Reducing the minimum zone size from 5 cm to 1 cm in a one-dimensional test calculation eliminated this discrepancy, however. In the two-peak regions the agreement between the experimental data and the values presented here is very good. The resolution of the calculation is adequate for studying qualitatively the characteristics of the flow field. For future work we recommend that the transition region be explored with improved resolution.

II. DESIGN OF PROBLEM

The problem of a 1-KT nuclear detonation at 104 ft (31.7m) HOB was chosen since it can be scaled conveniently to various HE tests. The use of the 1KT standard is also expendient; one could, however, have used realistic initial conditions, such as the Los Alamos Scientific Laboratory RADFLO or Air Force Weapons Laboratory (AFWL) SPUTTER calculations. A simple constant ambient atmosphere was used with a density of 1.22×10^{-3} g/cm^3 and pressure 1.01×10^6 dyne/cm^2. To relate the energy and mass densities to the pressure, a real-air equation of state (EOS) was used. This "table-lookup" EOS is derived from Gilmore's data (Ref. 5.) and has been vectorized for the TI Advanced Scientific Computer at NRL (Ref. 6). Figure 2 illustrates the effective gamma versus specific energy per unit mass for different values of the density. The internal energy density used in the call to the EOS is found by subtracting kinetic energy from the total energy; this can be negative due to phase errors in the fluid variables. When this occurs, the value of the pressure is reset to zero.

The transition from regular reflection to double Mach reflection is known to occur at a ground range approximately equal to the HOB. Therefore, the size of the mesh should be roughly twice the HOB in both directions. The upper boundary should be far enough away from the blast front to be noninterfering. We set the boundaries at 5.5×10^3 cm for the radial direction and 1.035×10^4 cm for the axial direction. The fine grid in the radial direction contained 140 out of 200 total zones, each 5 cm in length. The largest zones initially filled the right section of the grid and were 80 cm in length. A smoothing involving 40 zones was performed between the region to guarantee that the zone sizes varied slowly. In the vertical direction the fine grid contained 75 out of 150 total zones, each 5cm in length. Beyond that region the zones increased geometrically by a factor of 1.112.

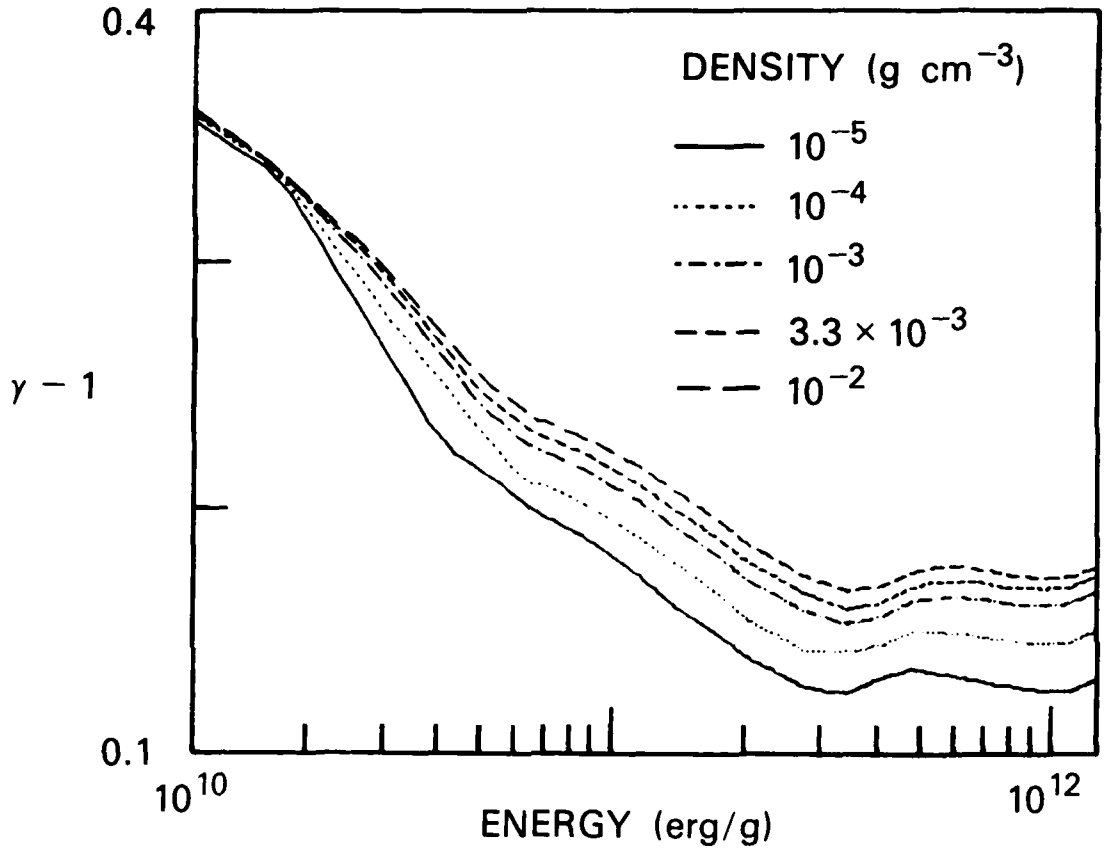

Fig. 2 - Gamma -1 vs. specific energy for Air EOS

Placement of the fine grid at the origin (ground zero - the point at which first reflection occurs) was determined to be optimum for capturing peak pressures in the airblast wave front. Thus, as the expanding wave moved along the ground surface, the fine grid was always locked to it, and each point along the incident blast front encountered the same spatial gridding as it approached the ground. By treating each point of the incident front in the same manner, we insured that the calculation was internally consistent and that the computed transition point was accurate to within the limits of the resolution. Finally, we point out that, as a section of the incident blast wave propagated within the fine grid, the wave steepened. The size of the fine grid was sufficient to insure that the incident wave had reached the maximum steepeness prior to intersecting the ground.

The initialization provides a strong shock with Mach number $M_I = 12$. This speed and the need for restart capability led to the choice of 200 timesteps as an interval for the spatial display ("snapshots"). The dump interval that resulted was $\sim \Delta t = 0.3$ milliseconds. These dumps were stored on magnetic tape and postprocessed.

Additional diagnostics were implemented in the calculation. Stations were created to gain information from fixed spatial positions within the calculational grid. These 25 physical variable sensors were placed along the ground and stored values of the energy and mass densities and velocity for every timestep. From this information one can construct static and dynamic pressure curves.

III. COMPUTATIONAL DETAILS

The evolution of the nuclear HOB flow field was modeled numerically with the FCT code FAST2D (Ref. 7). FCT yields accurate and well-resolved descriptions of shock wave propagation without the necessity of a priori knowledge of the essential gasdynamic discontinuities in the problem. Additionally, the code has a general adaptive regridding capability which permits fine zones to be concentrated in the region of greatest physical interest while the

remainder of the system is covered with coarse zones. Figure 3 depicts the grid setup initially and at transition to the double Mach stem structure. The rezone algorithm is programmed to track the Mach stem with the fine grid.

The transport algorithm used a low-phase-error phoenical FCT algorithm in a model called JPBFCT, an advanced version of the ETBFCT algorithm described in Ref 1. The linear part of this algorithm is fourth-order accurate spatially in advection problems with a given constant velocity and has a (nonlinear) flux-corrected antidiffusion needed to model shocks correctly. Finally, the transport subroutine is written in sliding-rezone form, which means that the mesh at the beginning and the end of the timestep need not be the same. Since the algorithm is one-dimensional, timestep splitting is employed to solve the 2-D problem.

The fluid transport routine JPBFCT is fully vectorized and requires about 2 μs per meshpoint-cycle. This time would have been still less if a vectorized fully two-dimensional routine had been used, since the 1-D loops are too short to permit full advantage to be taken of the vector capabilities of the NRL ASC. The table lookup in the EOS was also fully vectorized, so that pressure calculations required about 20% of the time needed for the hydrodynamics. These two items took up nearly all of the running time in the blast calculation itself. The cost of initialization was negligible, but the diagnositics cost up to 30% as much as the hydrodynamics, depending on how many of the various possible quantities were actually plotted. This latter number would be greatly reduced if the plot routines were fully vectorized.

A version of the AFWL 1 KT standard (Ref 8) was used to initialize the energy, density and velocity (flow field) at 3.76 milliseconds. The corresponding shock radius was 103.9 ft (31.69 m) peak overpressure of 1645 psi (1.134×10^4 K Pa). Because some areas of the grid were very coarse, interpolation onto the grid was performed. After the 1 KT flow was laid down inside a radius of 104 feet (31.7 m) the fine-zoned grid was activated to follow the peak pressure as it moved along

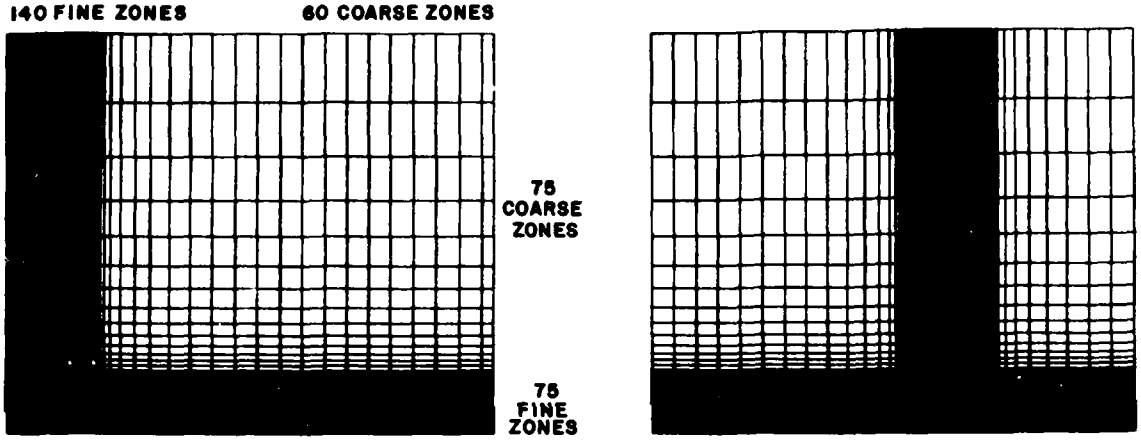

Fig. 3 - Adaptive gridding. The grid at initialization and at transition point (lines are drawn for every other zone, lines in fine-zone region are indistinguishable).

the ground surface, modelled as a perfectly reflecting boundary. This region comprised 140 zones, and a switch was set to keep 40 of these zones ahead of the reflection point. Permeable boundary conditions were used on the top and right edges of the mesh; i.e., density, pressure and velocity were set equal to ambient preshock conditions. Reflecting conditions were applied to the left and bottom.

The timestep was recalculated at every cycle according to the Courant condition

$$dt = 0.5 \min_{i,j} \frac{(\Delta x_i, \Delta y_j)}{(c+|V|)_{ij}} , \qquad (1)$$

where c is the speed of sound and $|V|$ is the modulus of the flow speed. This could have been relaxed somewhat by allowing violation of the local Courant limit at points ("hot spots") far from the region of chief physical interest. The total elapsed time in the 2-D calculation, 7.6 ms, required 5600 cycles.

Three types of diagnostics were employed, all in the form of plots made by post processing a dump tape. The first type of diagnostic consisted of CRT contour plots of density and static pressure, and arrows indicating the magnitude and direction of the velocity field, obtained at the dump intervals (every 200 cycles). The second type was pressure-range curves at z=0, obtained by finding the pressure peak(s) along the ground at each dump interval and hand-plotting them on the same graph. The third type consisted of pressure histories at a series of 24 stations, obtained by saving the energy and mass densities and the velocities at every cycle.

IV. RESULTS AND PHENOMENOLOGY

This calculation has been done to understand the violent effects of 1 KT of energy being released in the atmosphere at a HOB of 104 ft (31.7m). A strong spherical shock is created in the surrounding air, and reflects from the ground.

The outward-traveling airblast is then composed of two parts: one reflected upward approximately normal to the ground, and the original spherical blast. The peak pressure is coincident with the intersection of the two waves. This intersection continues to move outward until the angle of the spherical shock with respect to the ground reaches a critical value and the transition to a double Mach stem occurs. As shown by Ben-Dor and Glass (Ref. 9), this angle depends upon the incident strength of the shock (Fig. 4). Shocks with Mach numbers greater than 10 are not shown. Initially, the Mach number for the HOB simulation is well above 10. The Mach number at transition is approximately 11 and the angle is less than 50^{o}. From Fig. 4 the corresponding region is double Mach reflection.

Figure 1 has been labeled with the notation of Ben-Dor and Glass (Ref. 9). It should be noted that what is generally regarded as the second Mach stem is in fact the second reflected wave, which is part of the second Mach structure. To be consistent, one must label the second Mach stem as M_1 at the indicated location. The definition used is the state of the fluid one obtains by passing through one shock wave (M_1) or two shock waves (R and R_1). The first reflected wave R becomes the incident wave for the second Mach structure. Density contours are shown in Fig. 5 for an planar shock on wedge with a Mach number of 7 and an angle of 50^{o}. The complimentary figure illustrates the proper labeling of the multiple waves. Comparison of Fig. 5 and the HOB simulation (Fig. 6) shows that corresponding waves can be identified. Differences between the planar shock on wedge and the HOB can be explained in terms of the unsteady nature of the HOB case (a spherically expanding wave that continuously decreases in Mach number and angle.) Although the term irregular Mach reflection has been used to describe the complex shock structure that evolves from HOB events, we believe it to be very regular and explainable as a double Mach reflection that evolves as a function of time.

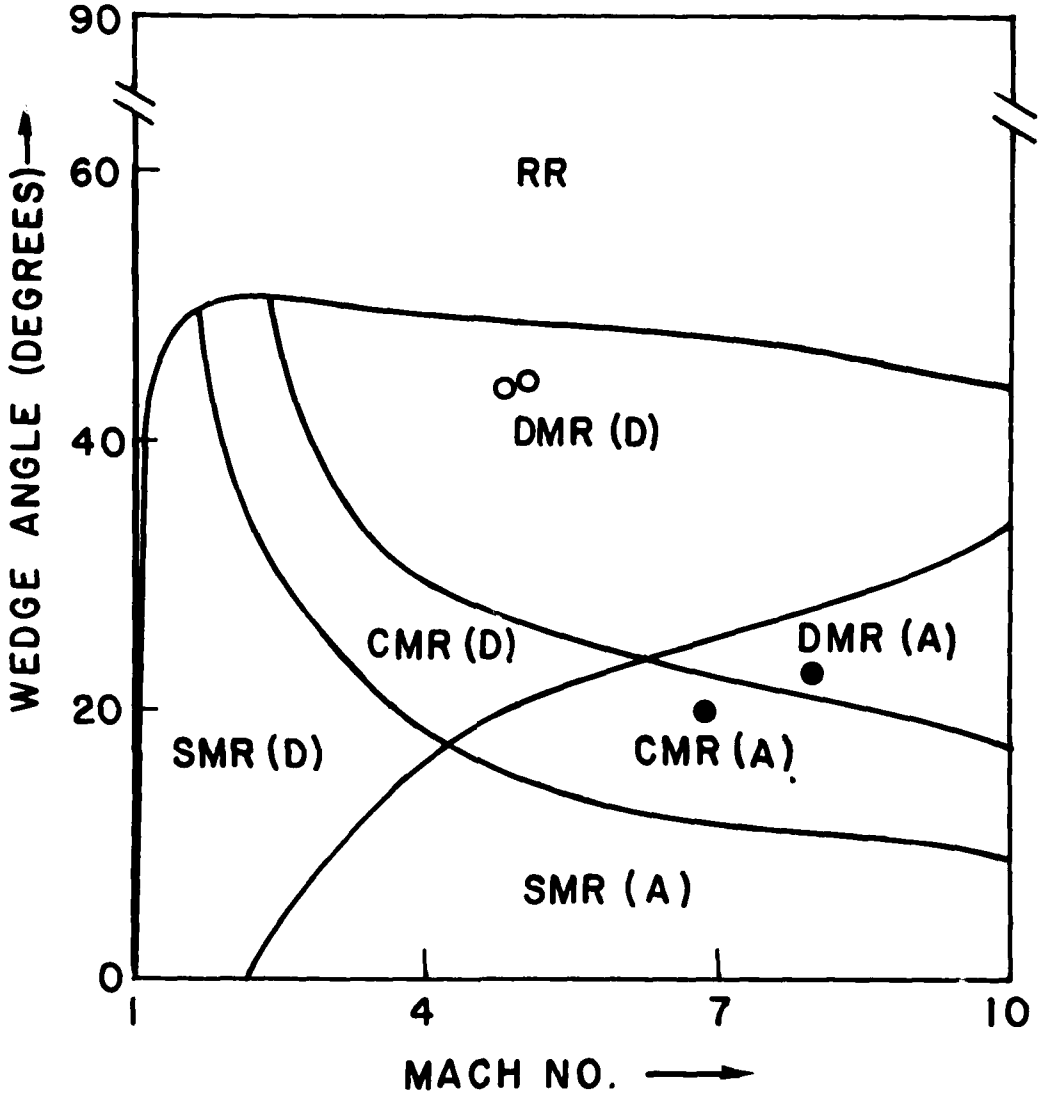

Fig. 4 - Types of shock reflection: RR, CMR, SMR, and DMR denote regular reflection and single, complex and double mach reflection, respectively. The D and A refer to attached and detached shocks.

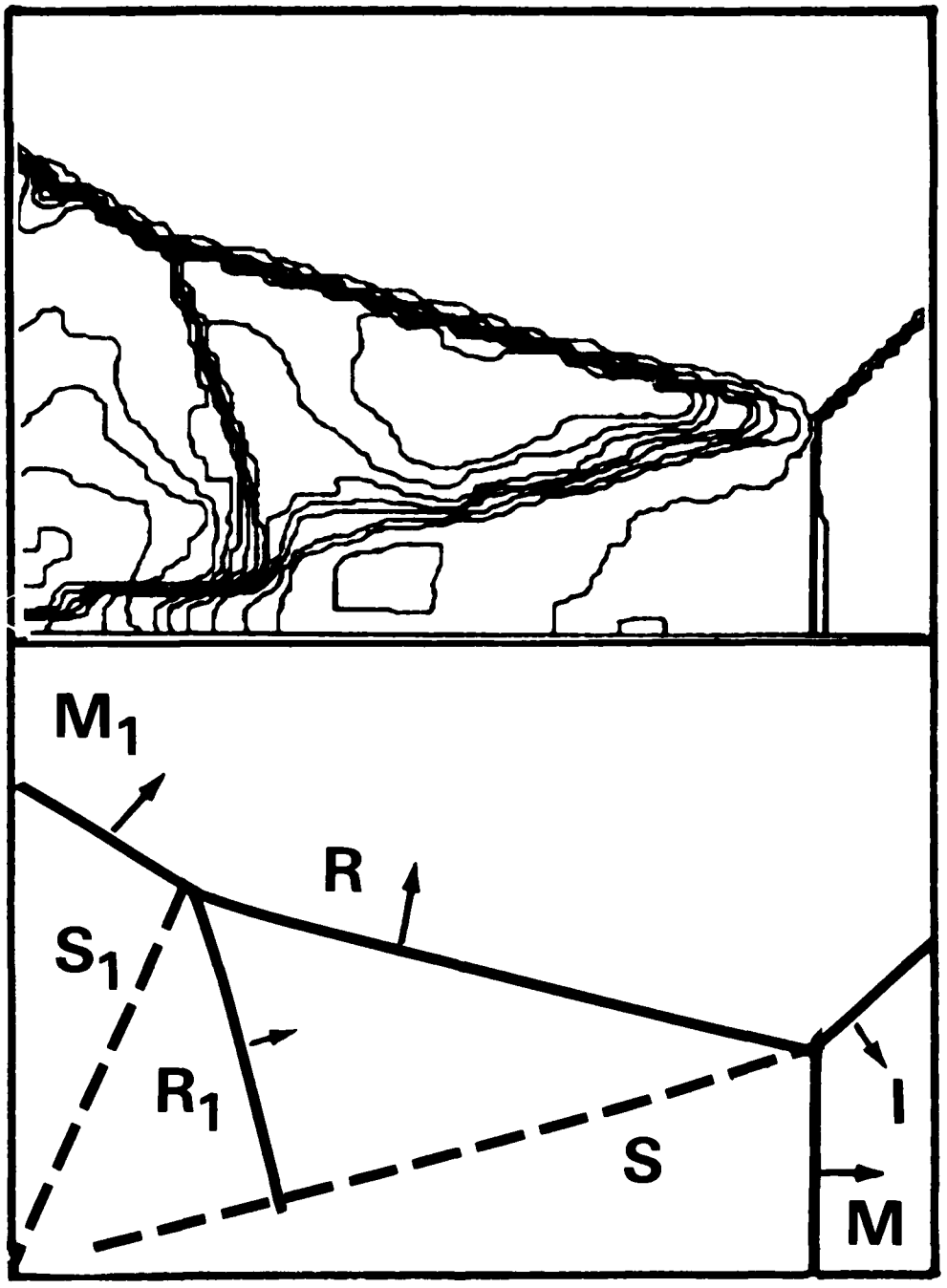

Fig. 5 - Planar shock (Mach 7) on 50° wedge with wave identification

The HOB numerical simulation begins just before the shock first reflects from the ground. As a summary of how the flow field then develops, we present snap-shots at the important stages. (A more complete display is presented in Appendix A). Figure 6a indicates the pressure and density contours and velocity vectors at t = 3.18 ms. In Fig. 6b the reflected shock is shown moving upward, the outward flow begins to stagnate at the ground (transition). Fig. 6c, at t = 5.99 ms, shows an enlargement of the shock front, and the development of the Mach stem, slip surface and second Mach stem. The angle of the shock with respect to the ground is increasing with time, so that the effective wedge angle is decreasing. From the work of Ben-Dor and Glass one expects a transition to double Mach stem to occur at approximately 45^{o}. The angle in Fig. 6b is about 45^{o} and the shock front has entered the transition phase. Figure 6d shows the fully developed shock structure at 7.79 ms. Toeing out of the first Mach stem can be also seen in the contours of Fig. 6d and occurs as the fluid rolls forward where the slip line would otherwise intersect the ground. The velocity field in Fig. 6d also shows this detail.

Note the reflected shock properties (that part of the structure that contains the second Mach stem M_1). The reflected shock propagates rapidly through the high temperature fireball, due to the high local sound speed. The shape of this reflected wave is a primary difference between the HOB case and the planar wave on wedge case. The other major difference, of course, is the spherically expanding blast wave which decreases in strength approximately as r^{-2}.

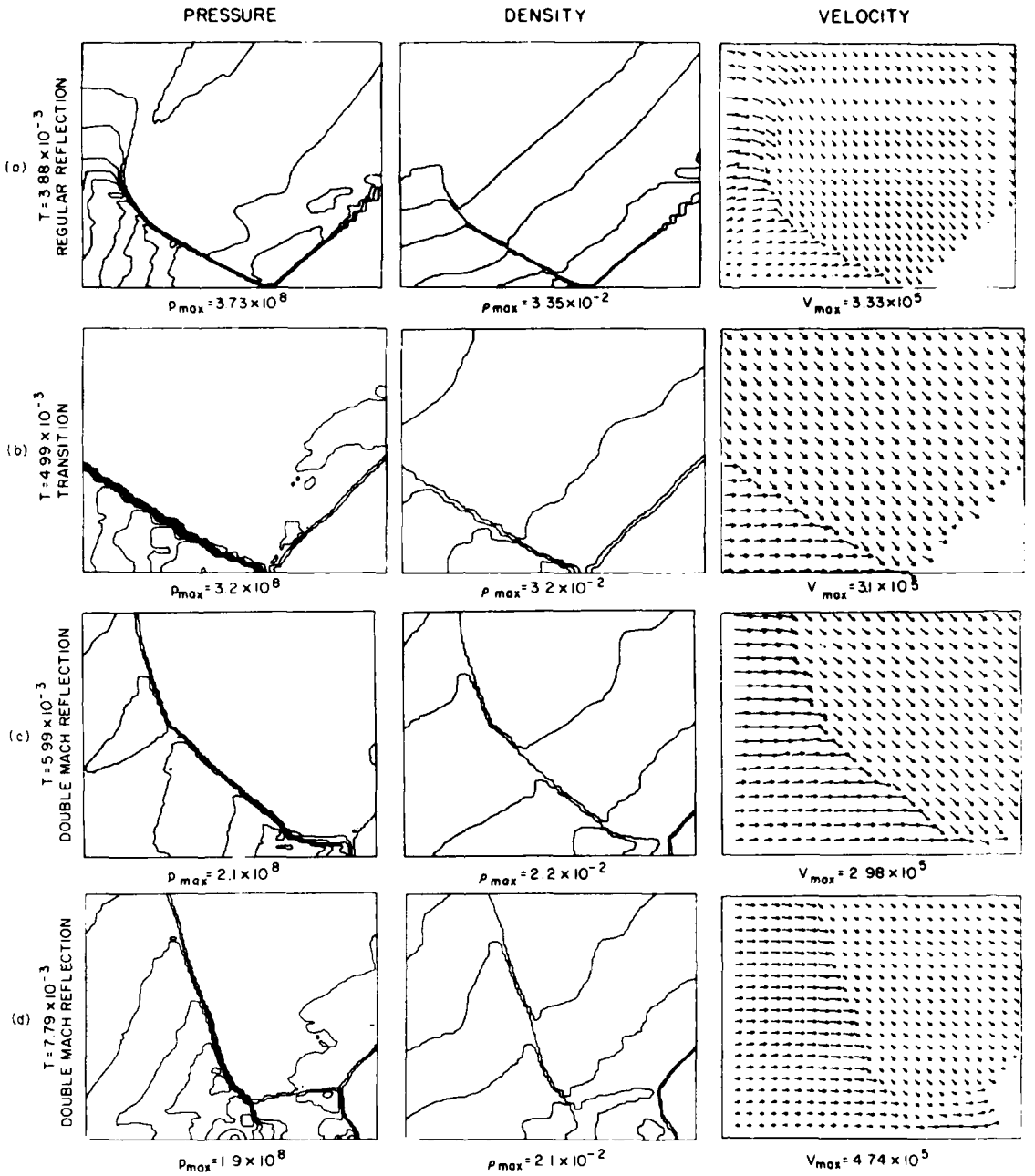

Fig. 6 - Pressure, density, and velocity fields for HOB calculation (a) in regular reflection state; (b) at transition to Mach reflection; (c) shortly afterward, when second peak has become larger than first; and (d) fully developed (note toe at base of first Mach stem). Units in cgs.

An effective way to quantitatively evaluate the calculation and observe in detail the transition to a Mach stem regime can be seen by examining the station data. The station sensors were placed in the bottom row of the calculation 100 to 200 cm apart. In Table I the maximum pressure recorded for each station along with the location can be found.

Besides giving a reliable value for the peak pressure to be used for constructing the pressure-distance curve, these data allow one to see effects fixed in space but varying in time. Figure 7 is a superposition of the pressure profiles from stations 15 to 24 (the transition region). Noteworthy is the profile from station 17, which is the first station to record a second peak on the back side. At station 19, 200 cm further away from ground zero, the second peak is almost equal to the first. The visible transition (as seen in Fig. 6b, occurs at a ground range between 3100 cm and 3300 cm (stations 19-21) revealing a dominant second peak and a "first peak" (i.e., first seen by the sensor) that is about half the magnitude of the second. The second peak does not exhibit a sharp almost discontinuous rise and then a rapid but slower decrease along the back side. Instead, it has the appearance of a density compression. This behavior has dramatic consequences for military planners because the pressure-distance curve is modified and the dynamic pressure is enhanced.

The analogous profiles for dynamic pressure are presented in Fig. 8. Again data from stations 15 to 24 is utilized. The development of the second peak and its correlation with the Mach stem formation can be observed. There is, in addition, a noticeable increase in the first peak values (station 15 to the maximum at station 18). After the structure becomes visibly resolved (station 20 and beyond) the second peak resembles a rounded profile suggesting the formation of a stagnation region behind the first peak (Mach stem).

Table 1

Station No.	Location (cm)	Time (sec)	Pres (dynes/cm^2)
1	2.0000E 02	2.25E-04	8.11E 08
2	4.0000E 02	2.80E-04	7.92E 08
3	8.0000E 02	5.28E-04	7.17E 08
4	1.0000E 03	7.23E-04	6.73E 08
5	1.2000E 03	9.54E-04	6.24E 08
6	1.4000E 03	1.23E-03	5.65E 08
7	1.6000E 03	1.54E-03	5.21E 08
8	1.8000E 03	1.91E-03	4.70E 08
9	2.0000E 03	2.34E-03	4.54E 08
10	2.2000E 03	2.81E-03	4.14E 08
11	2.3000E 03	3.07E-03	4.03E 08
12	2.4000E 03	3.35E-03	3.92E 08
13	2.5000E 03	3.62E-03	3.82E 08
14	2.6000E 03	3.88E-03	3.73E 08
15	2.7000E 03	4.19E-03	3.37E 08
16	2.8000E 03	4.48E-03	3.33E 08
17	2.9000E 03	4.79E-03	3.05E 08
18	3.0000E 03	5.11E-03	3.01E 08
19	3.1000E 03	5.41E-03	2.33E 08
20	3.2000E 03	6.06E-03	1.96E 08
21	3.3000E 03	6.49E-03	1.79E 08
22	3.4000E 03	6.82E-03	1.87E 08
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24	3.6000E 03	7 .73E-03	1.69E 08

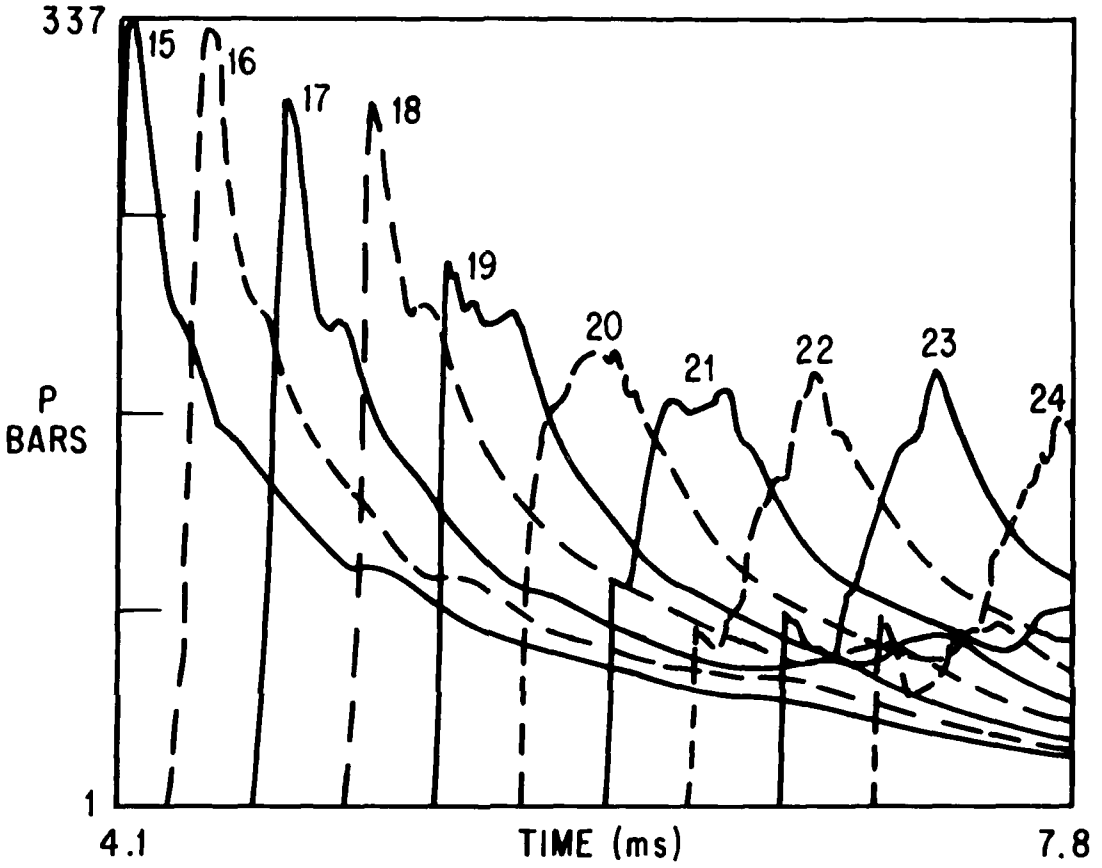

Fig. 7 - Station pressure data (nos. 15-24)

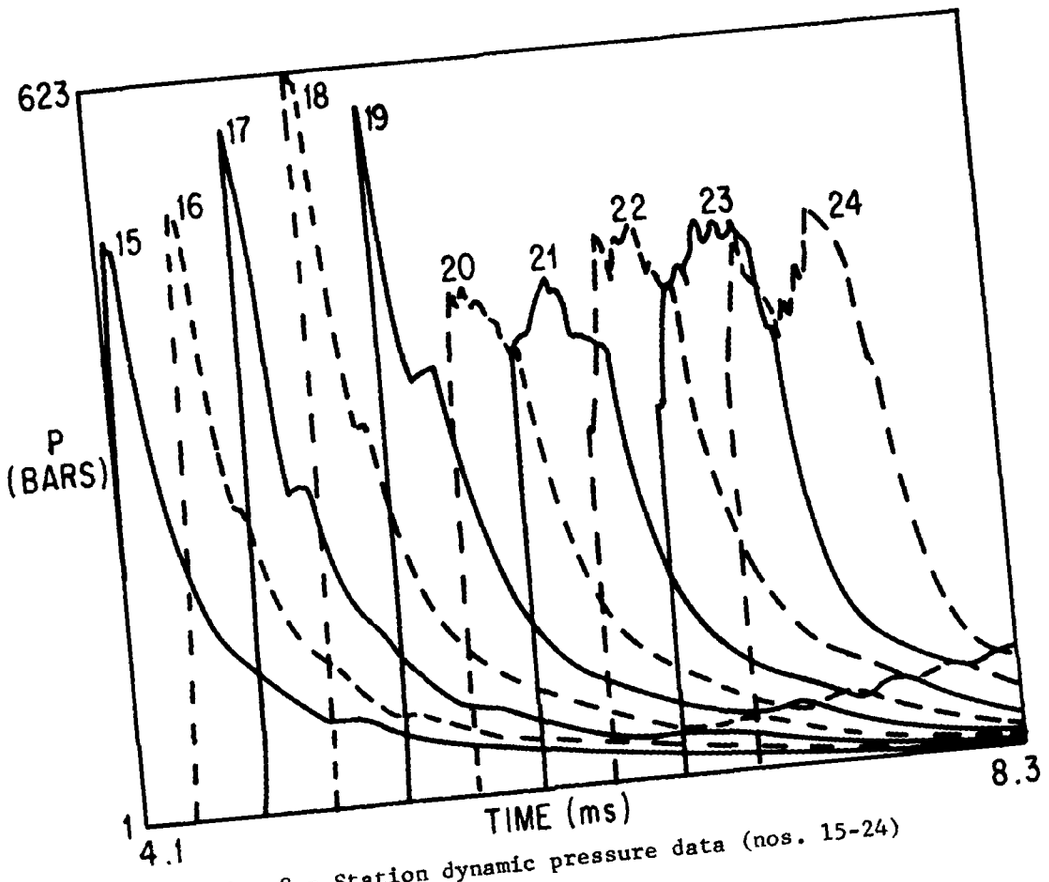

Fig. 8 - Station dynamic pressure data (nos. 15-24)

Finally we consider the pressure-distance relation for the HOB case. In Fig. 9 we compare the results of the numerical simulation with the data of Carpenter and with empirical analysis. Carpenter's data are based upon careful HOB experiments with 8 lb PBX9404 spheres. The empirical analysis was based on a 1 KT nuclear free air curve and HOB construction factors. The calculated values in the regular reflection regime are 20% low, which may be attributed to a combination of FCT clipping, the resolution of the grid, and inaccuracies in the initialization of the flow field. During and after Mach reflection, the peaks remain low until the Mach stem structure has grown large enough to be resolved on the mesh. By the time it occupies a region of 15 cells high and 35 cells wide, the peak pressures are in good agreement with the HE data and the empirical analysis.

Other attempts to model the transition region have been made. Needham and Booen (Ref. 10) present results of a 1100 lb pentolite sphere at 15 feet HOB. The general phenomena of the flow field can be seen from their simulation. When a pressure distance curve is constructed from this calculation, one finds that in the regular reflection region their results are 15% to 30% high relative to theory. After transition to double Mach reflection the first peaks are 20% low while the second peaks are 40% low (Ref. 4).

V. SUMMARY

The airblast from a 1KT nuclear event at 104 ft HOB has been numerically simulated with the FAST2D computer code. The results give insight to the formation and subsequent evolution of the Mach stem, the triple point, and the contact discontinuity. The transition from regular reflection to double Mach reflection is predicted. We suggest that the first signal for

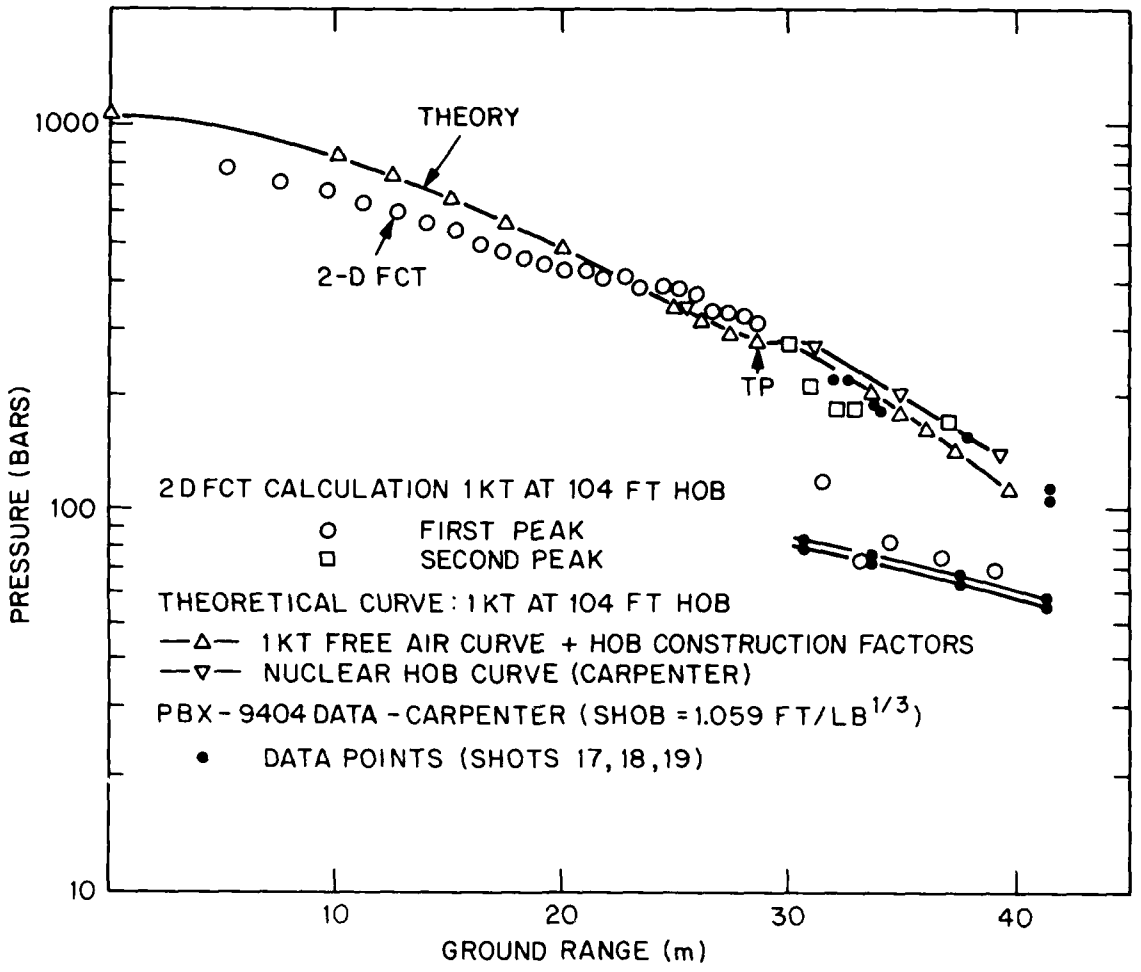

Fig. 9 - Pressure-range curves for first and second (after transition - denoted by TP - to double Mach reflection) peaks

transition is the appearance of a second peak behind the shock front due to stagnation in the flow. Comparison with the pressure-distance curves of Carpenter and Kuhl indicates agreement within 20%. Both first and second peaks are predicted with similar accuracy.

ACKNOWLEDGEMENT

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References

1. Boris, J.P., Flux-Convected Transport Algorithms for Solving Generalized Continuity Equations, NRL Report #3237 (1976)

2. Boris, J.P., Book, D., "Flux-Corrected Transport I: SHASTA, a Fluid Transport Algorithm that Works", J. Comp. Phys., 11, 38 (1973).

3. Carpenter, H.J., Height-of-Burst Blast at High Overpressure, 4th International Symposium on Military Applications of Blast Simulation (1974).

4. Kuhl, A. (Private Communication,1981).

5. Gilmore, F.R., "Equilibrium Composition and Thermodynamic Properties of Air to 24,000^{o}K", RM-1543 (Aug 1955).

6. Young, T.R. (Private Communication,1981).

7. Book, D., Boris, J., Kuhl, A., Oran, E., Picone, M., and Zalesak, S. Simulation of Complex Shock Reflections from Wedges in Inert and Reactive Gaseous Mixtures, Proceedings of Seventh International Conference on Numerical Methods in Fluid Dynamics, Springer-Verlag, Stanford, 1980.

8. Needham, et al.,AFWL 1 KT Nuclear Airblast Standard, AFWL TR-73-55, Air Force Weapons Laboratory (April 1975).

9. Ben-Dor., Glass I.I., Domains and Boundaries on Non-Stationary Oblique Shock-Wave Reflections, I. Diatomic Gas, J. Fluid Mechanics, Vol. 92, Pt. 3, pp. 459-496 (1979).

10. Boen, M.W., and Needham, C.E., Two Dimensional Hull Code Simulation of Complex and Double Mach Reflections, Technical Note No. NTE-TN-81-001, Air Force Weapons Laboratory, New Mexico, January 1981.

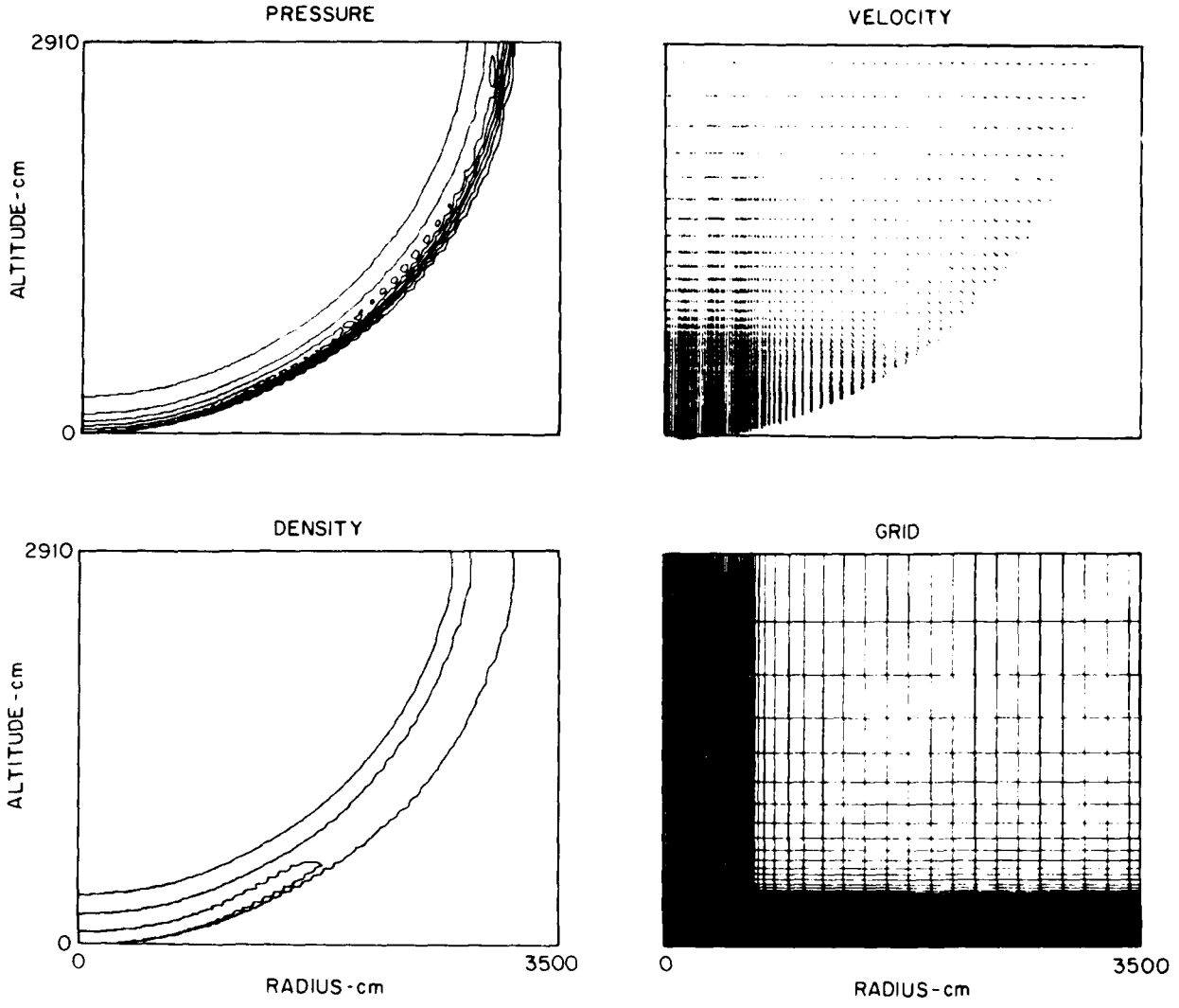
APPENDIX A. DETAILED TIME HISTORY OF CALCULATION

The following figures comprise a temporal history of the numerical simulation. Each page contains pressure contours, velocity vectors, density contours, and the corresponding grid for a particular time. The series begins at $t_o = 0$ ($t_I = 3.76$ ms) and continues to $t_F = 8.28$ ms.

1 kt AT 104 ft HOB

TIME = 0.0 msec

CYCLE = 0



1 kt AT 104 ft HOB

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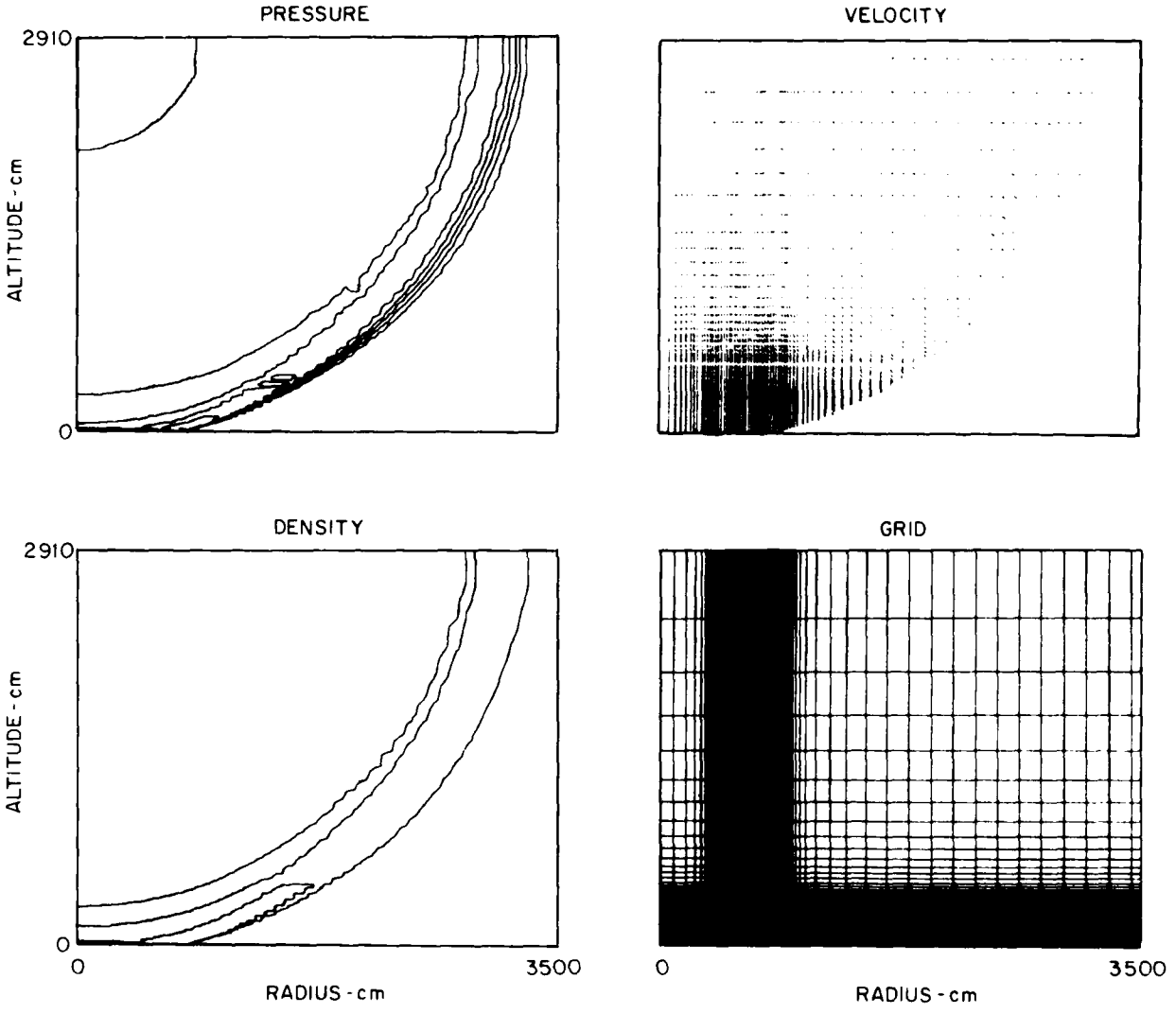
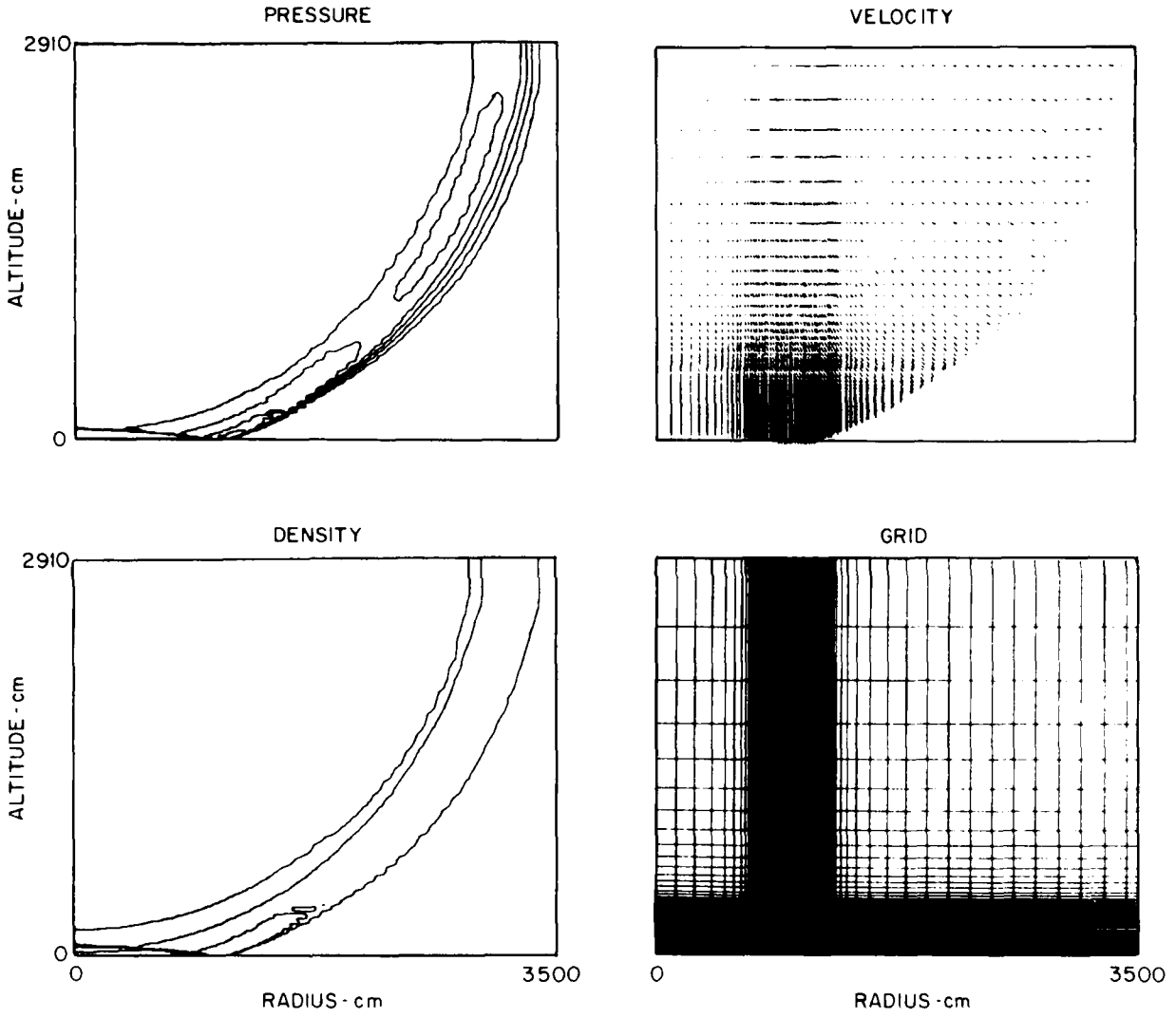
CYCLE = 400



1 kt AT 104 ft HOB

TIME = 0.91 msec

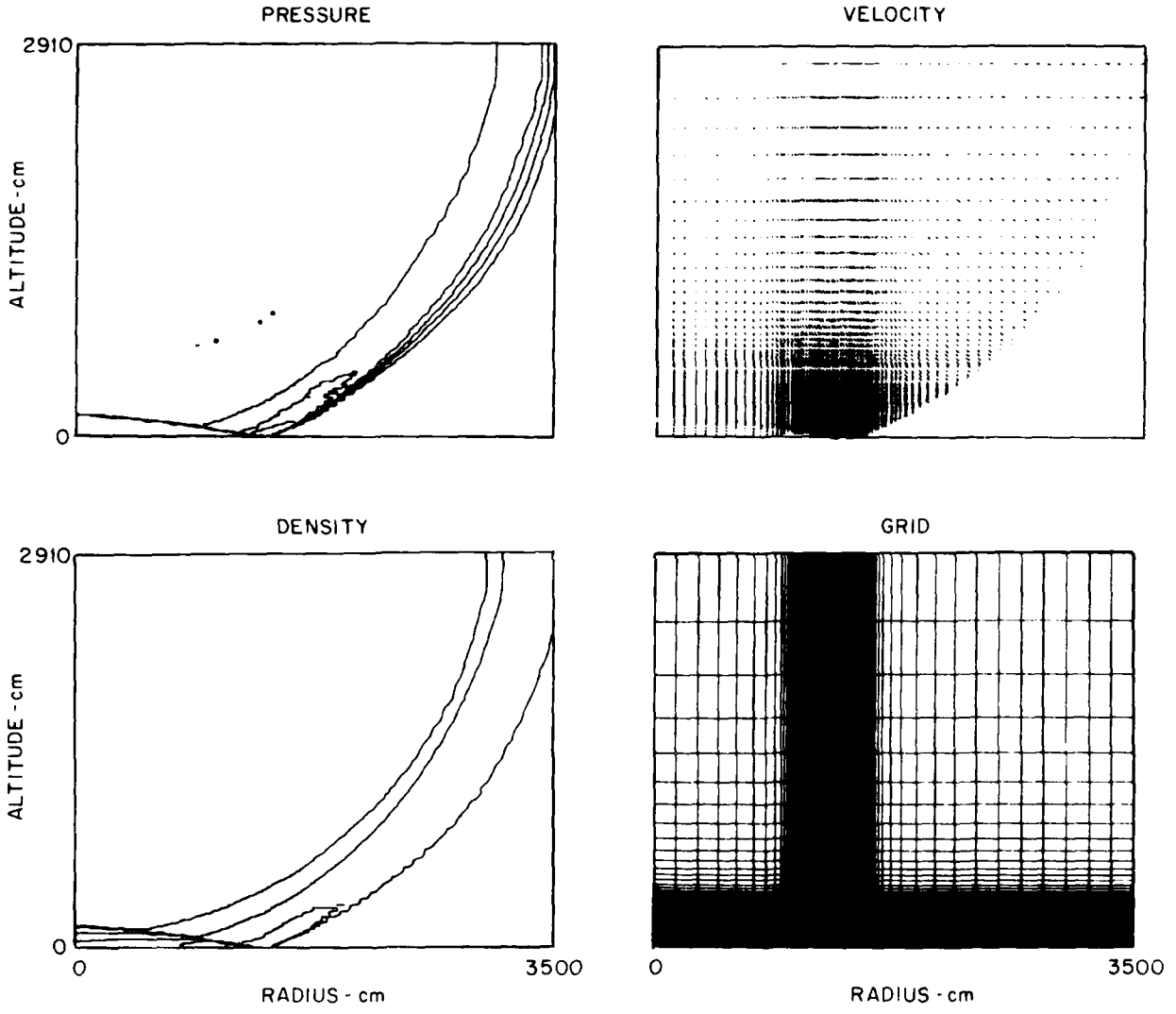
CYCLE = 800



1 kt AT 104 ft HOB

TIME = 1.05 msec

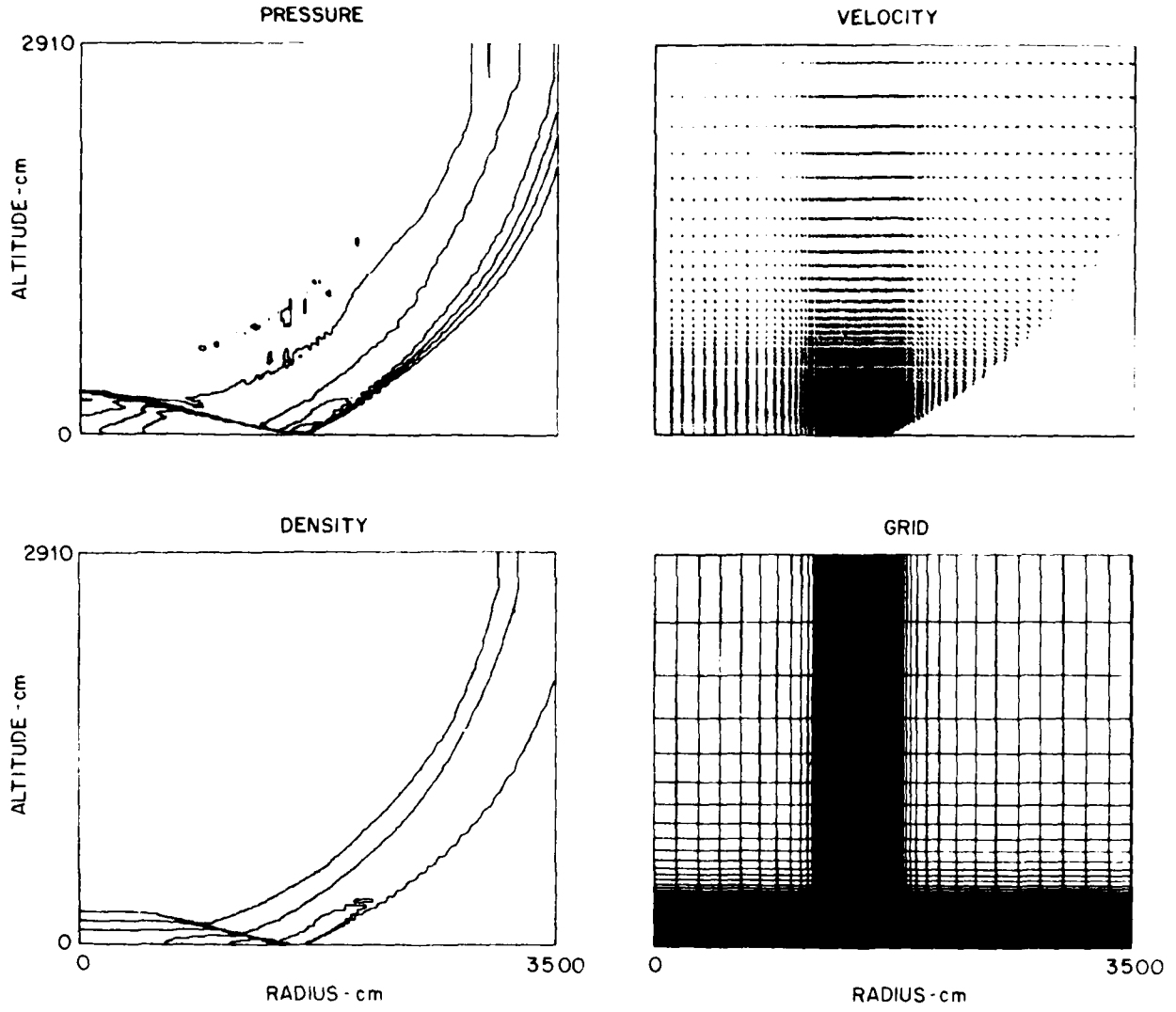
CYCLE = 1200



1 kt AT 104 ft HOB

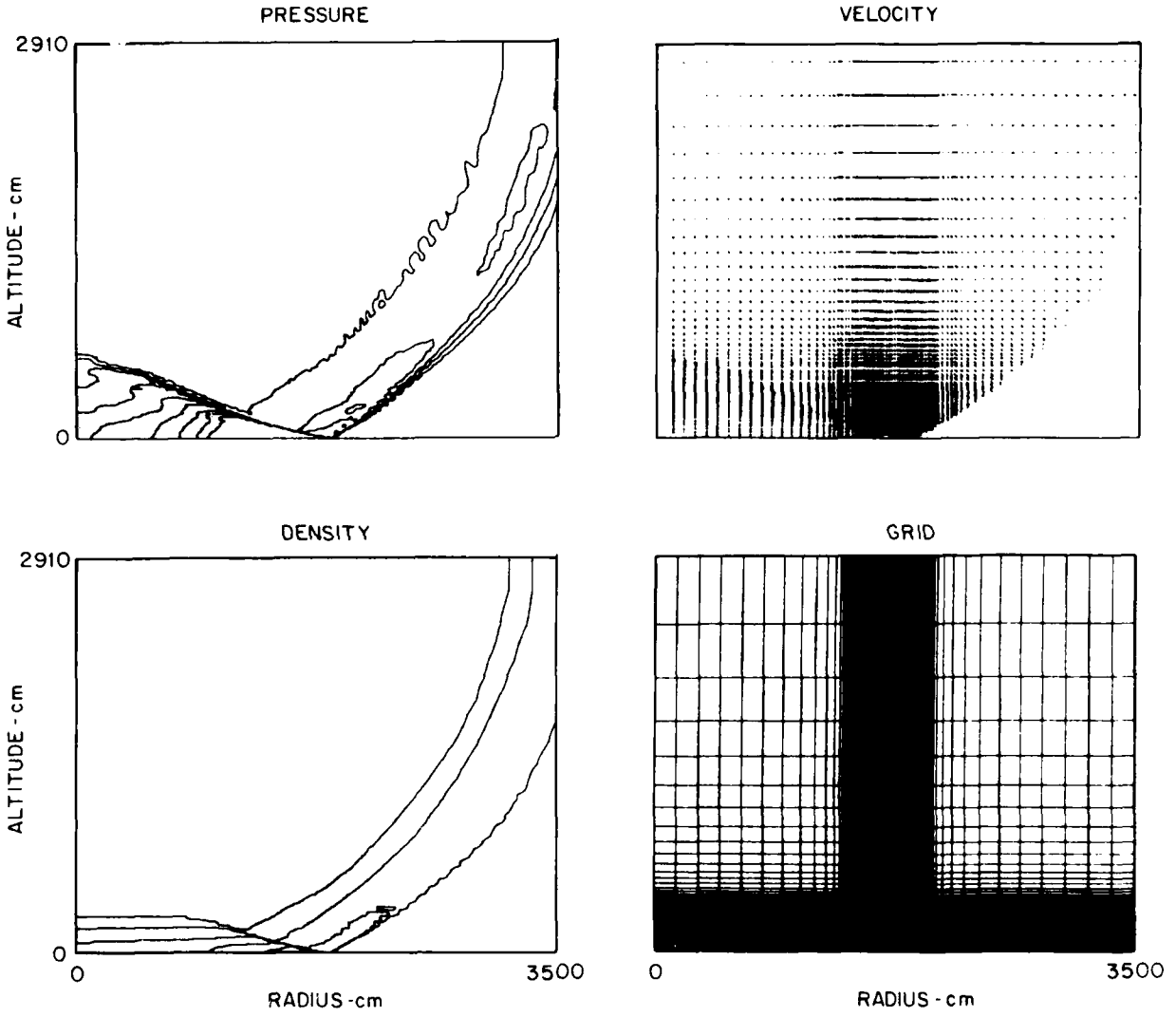
TIME = 1.42 msec

CYCLE = 1600



1 kt AT 104 ft HOB

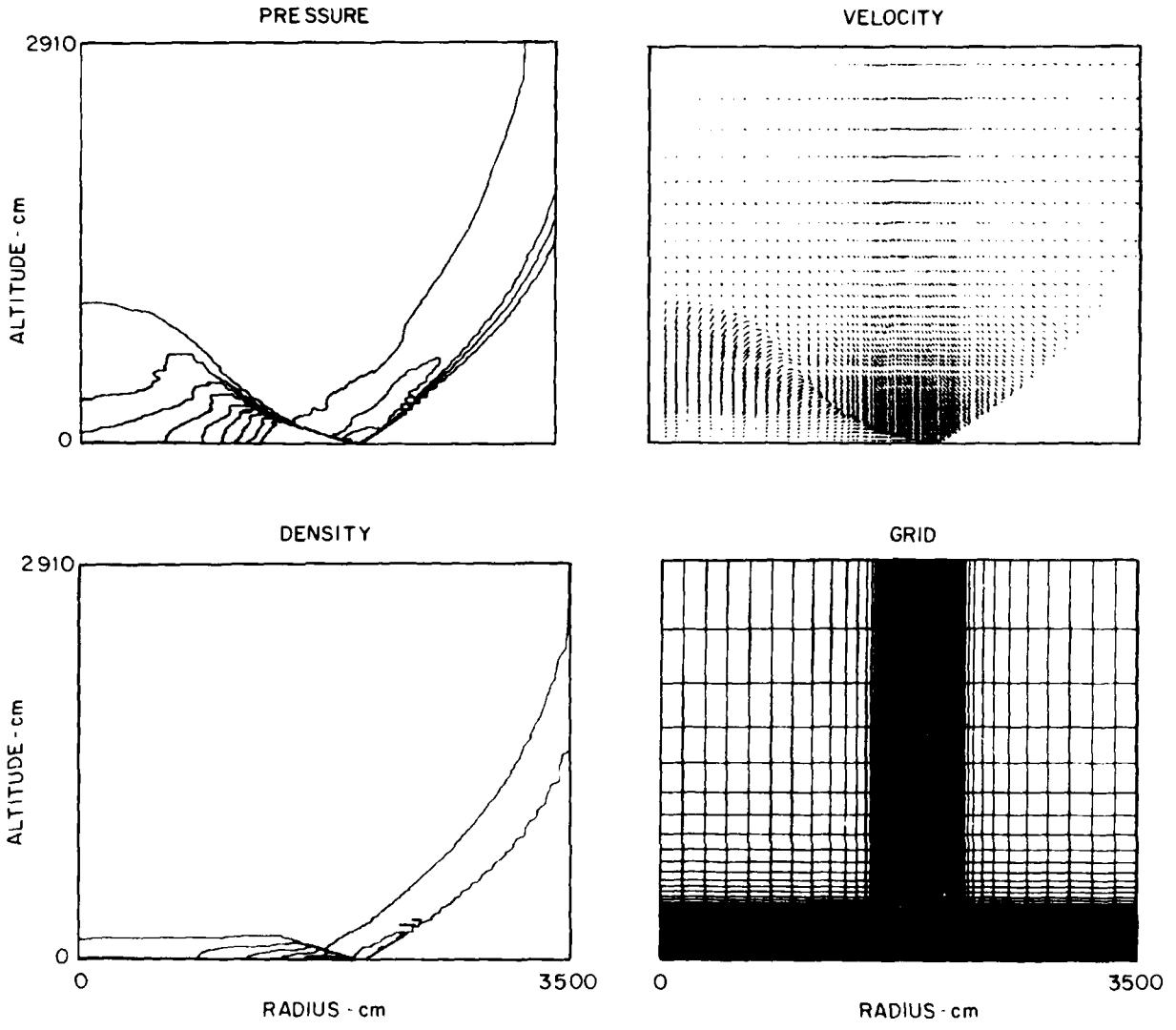
TIME = 1.80 msec
CYCLE = 2000



1 kt AT 104 ft HOB

TIME = 2.20 msec

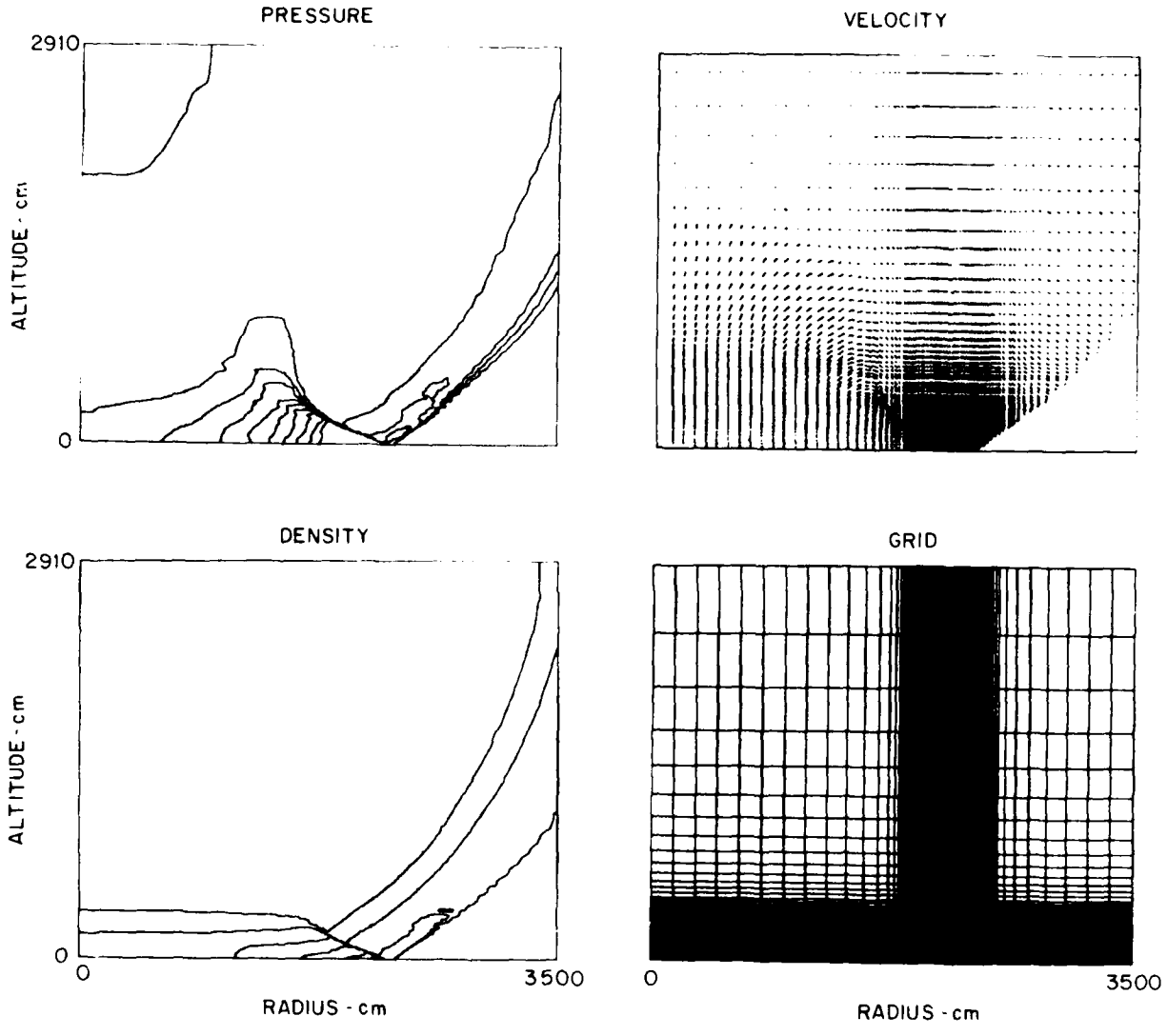
CYCLE = 2400



1 kt AT 104 ft HOB

TIME = 2.81 msec

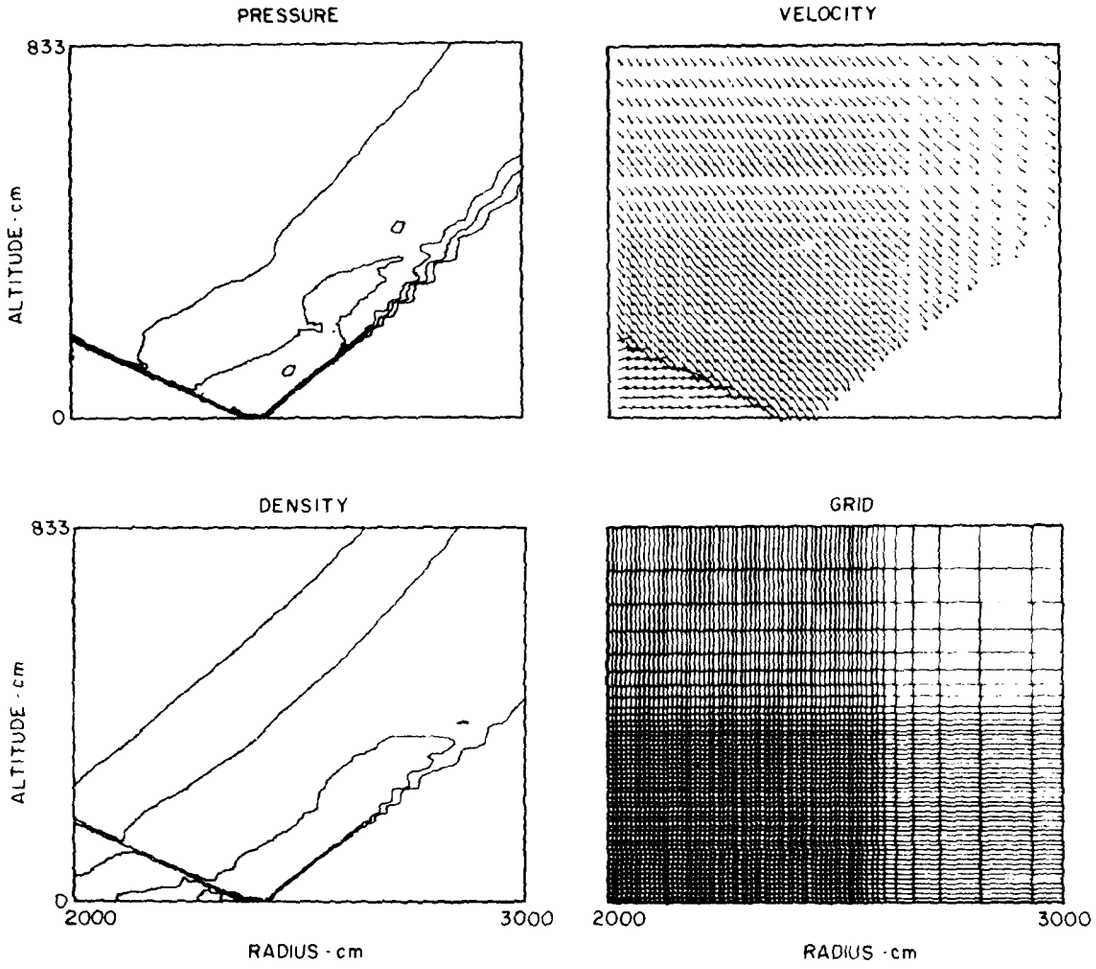
CYCLE = 3000



1 kt AT 104 ft HOB

TIME = 3.24 msec

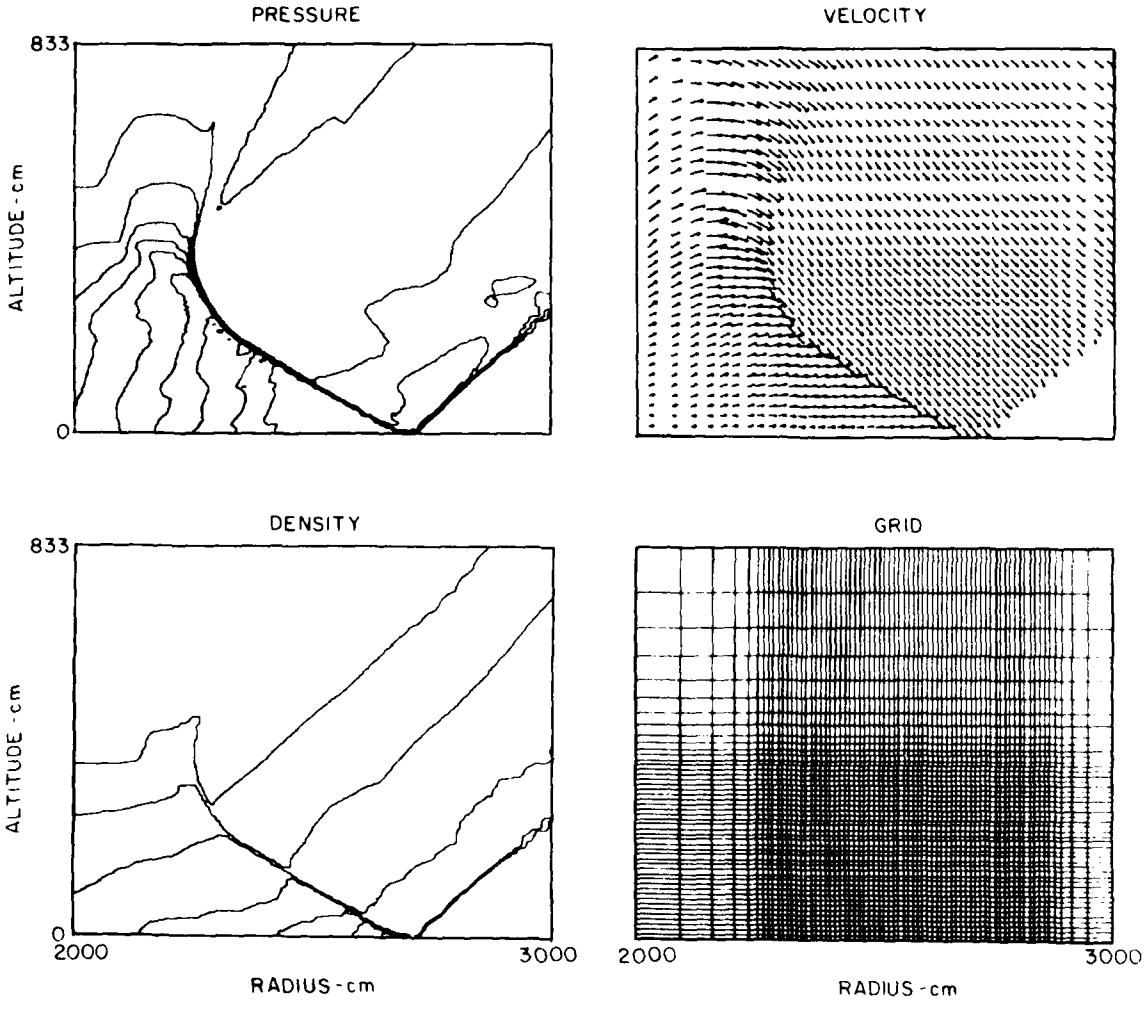
CYCLE = 3400



1 kt AT 104 ft HOB

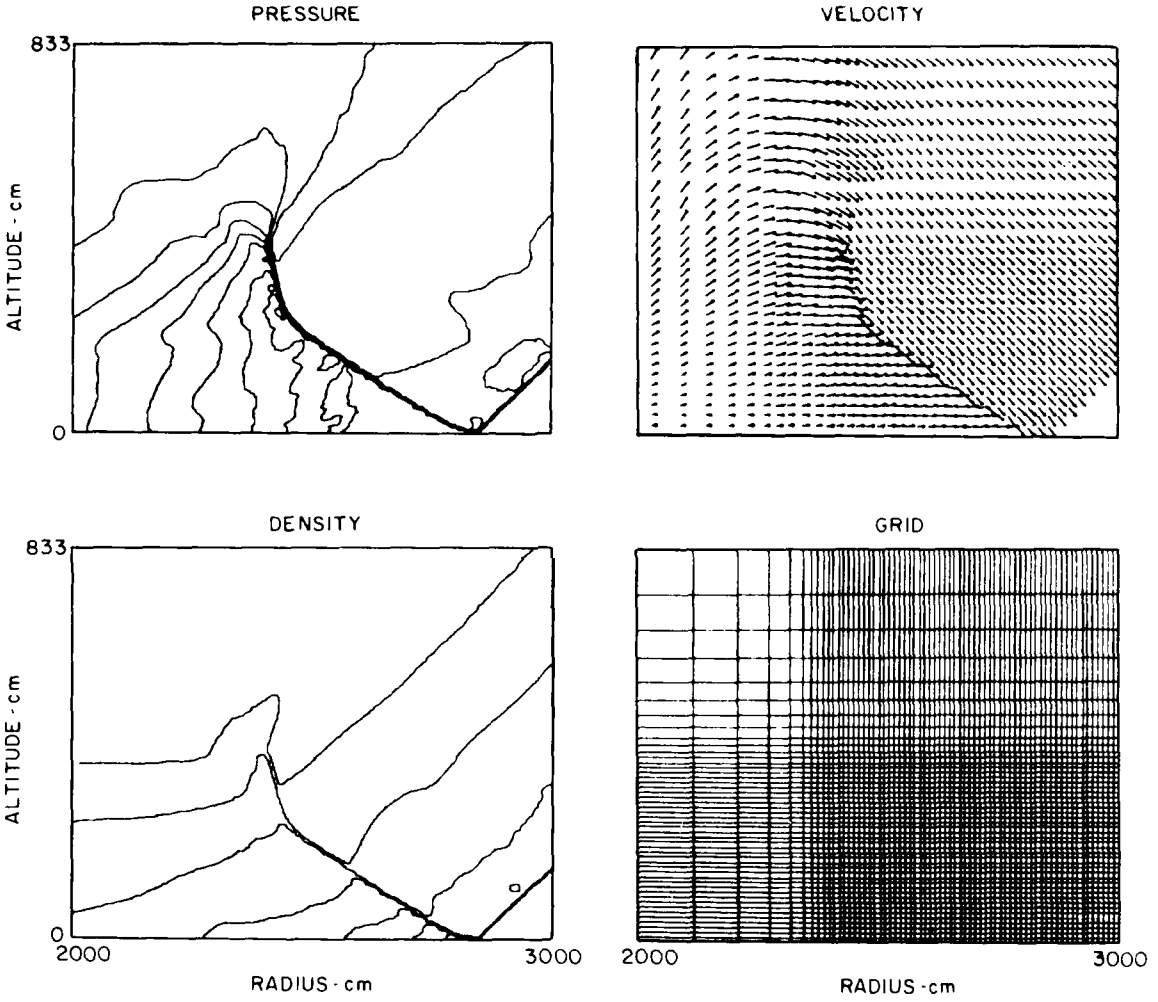
TIME = 4.10 msec

CYCLE = 4200



1 kt AT 104 ft HOB

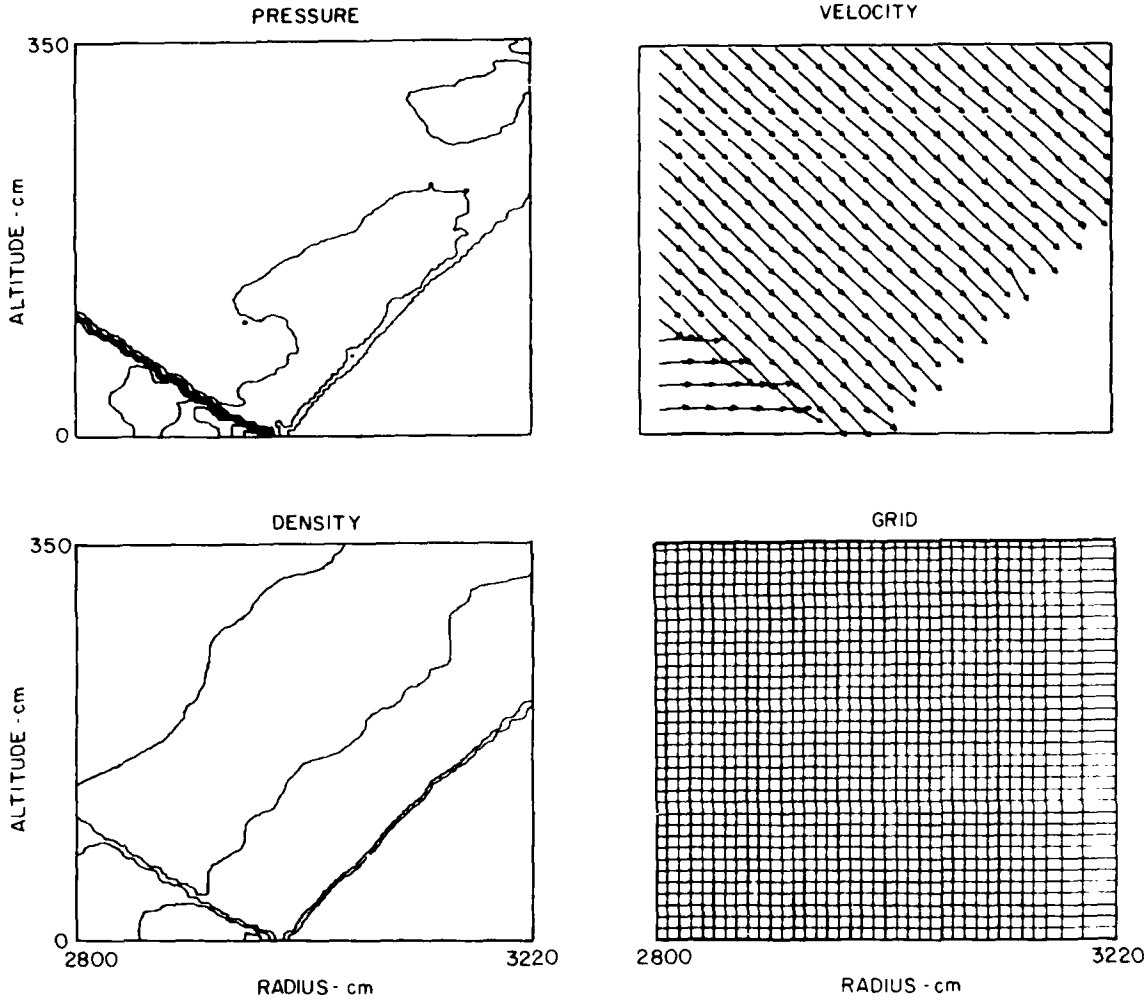
TIME = 4.54 msec
CYCLE = 4600



1 kt AT 104 ft HOB

TIME = 4.99 msec

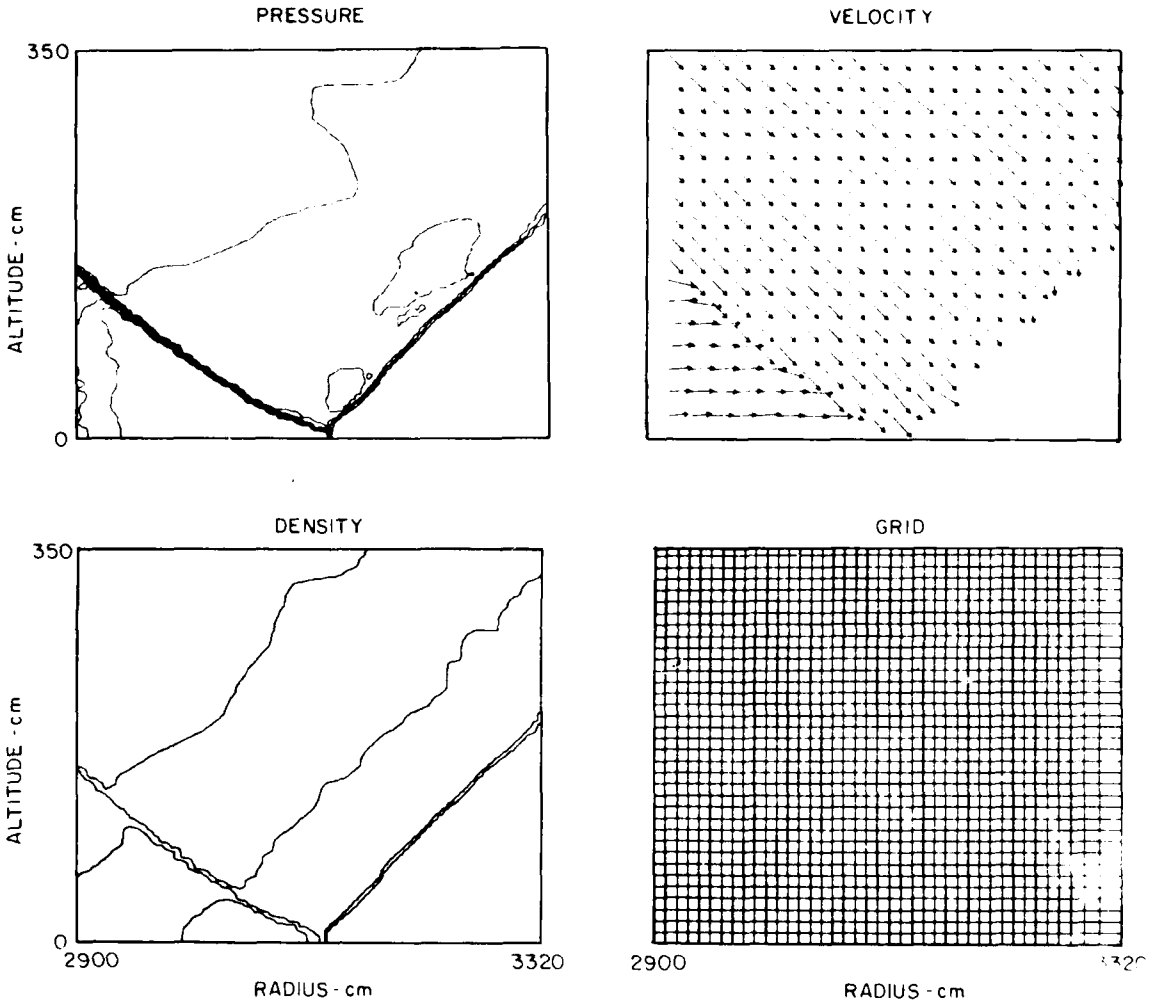
CYCLE = 5000



1 kt AT 104 ft HOB

TIME = 5.47 msec

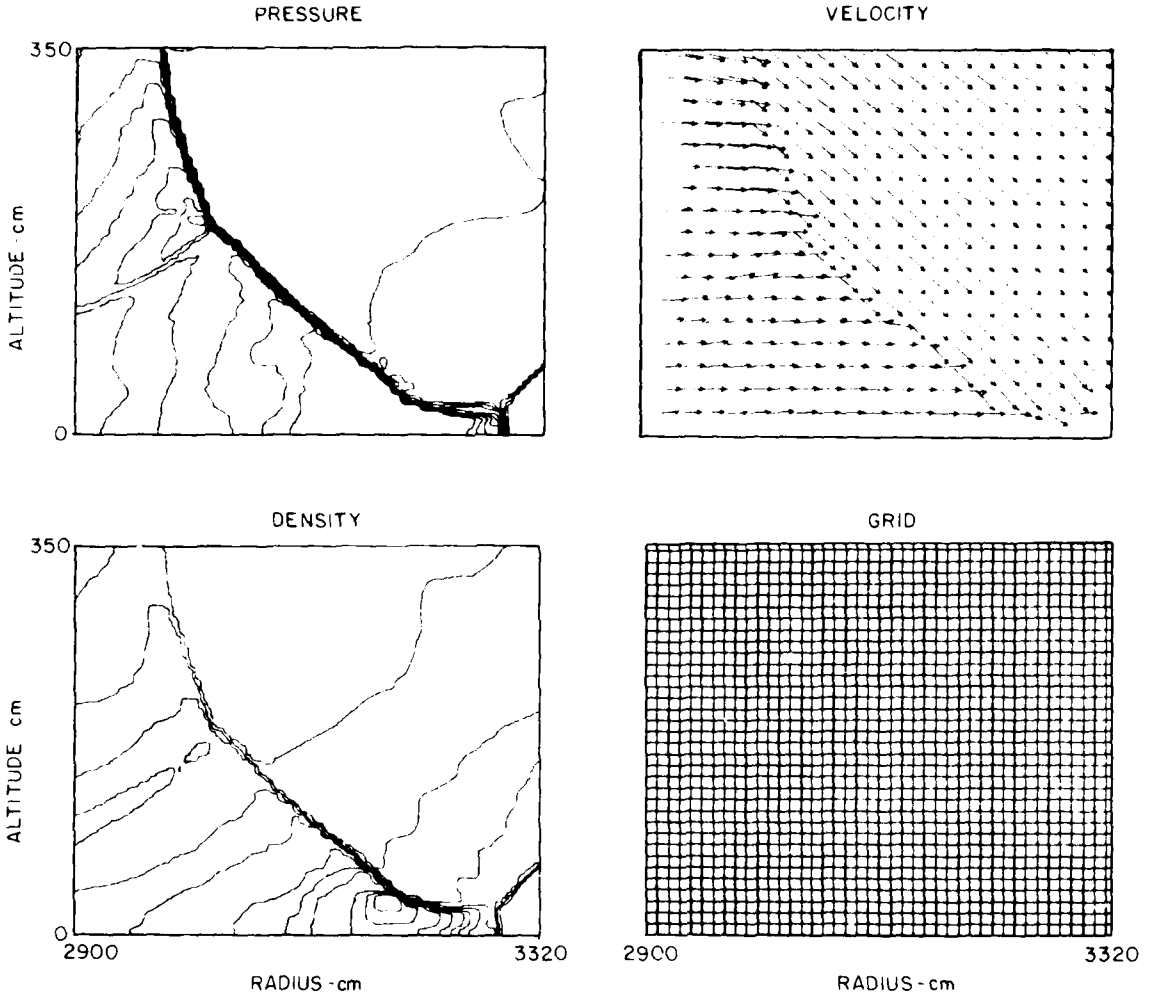
CYCLE = 5400



1 kt AT 104 ft HOB

TIME = 5 99 msec

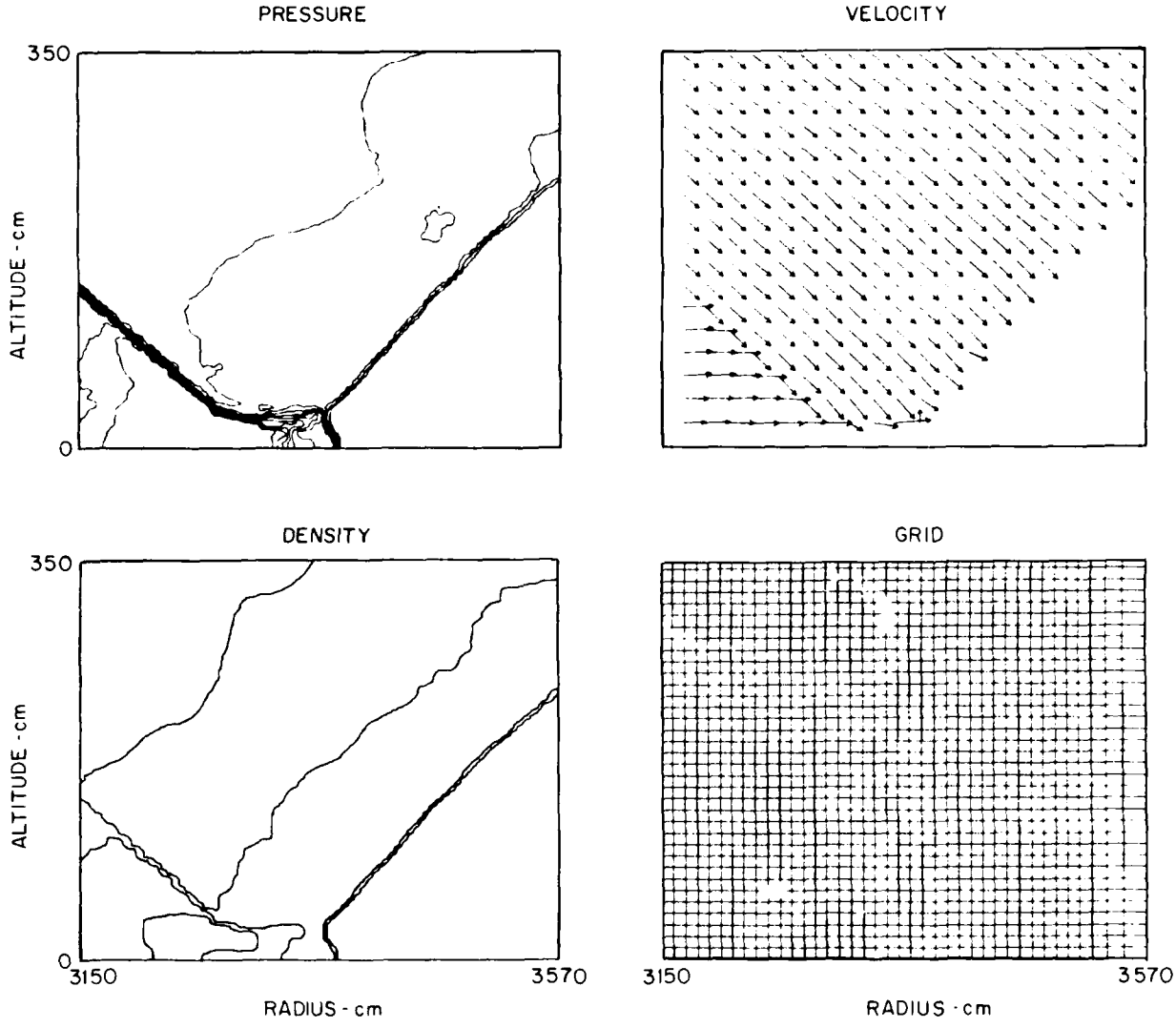
CYCLE = 5800



1 kt AT 104 ft HOB

TIME = 6.26 msec

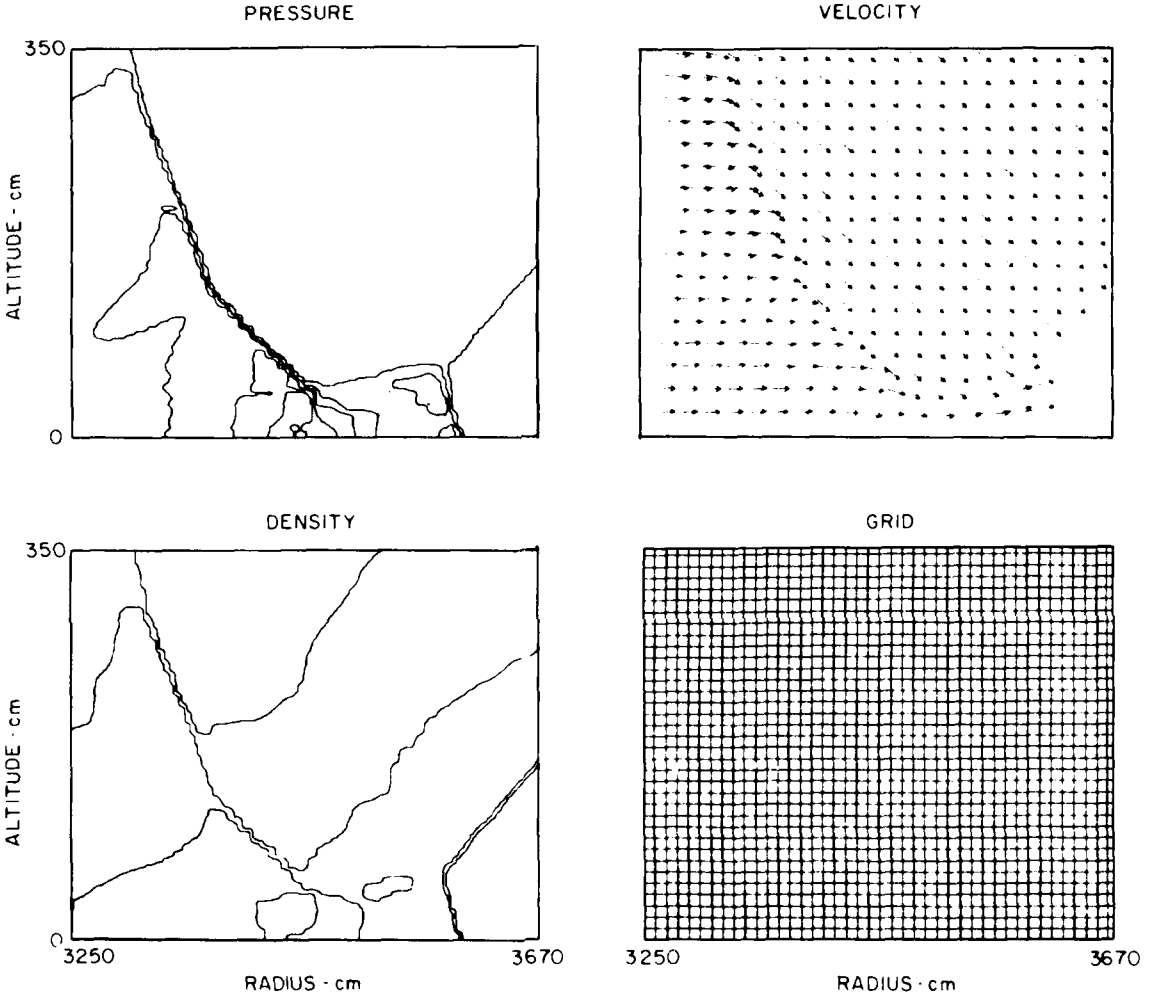
CYCLE = 6000



1 kt AT 104 ft HOB

TIME = 7 05 msec

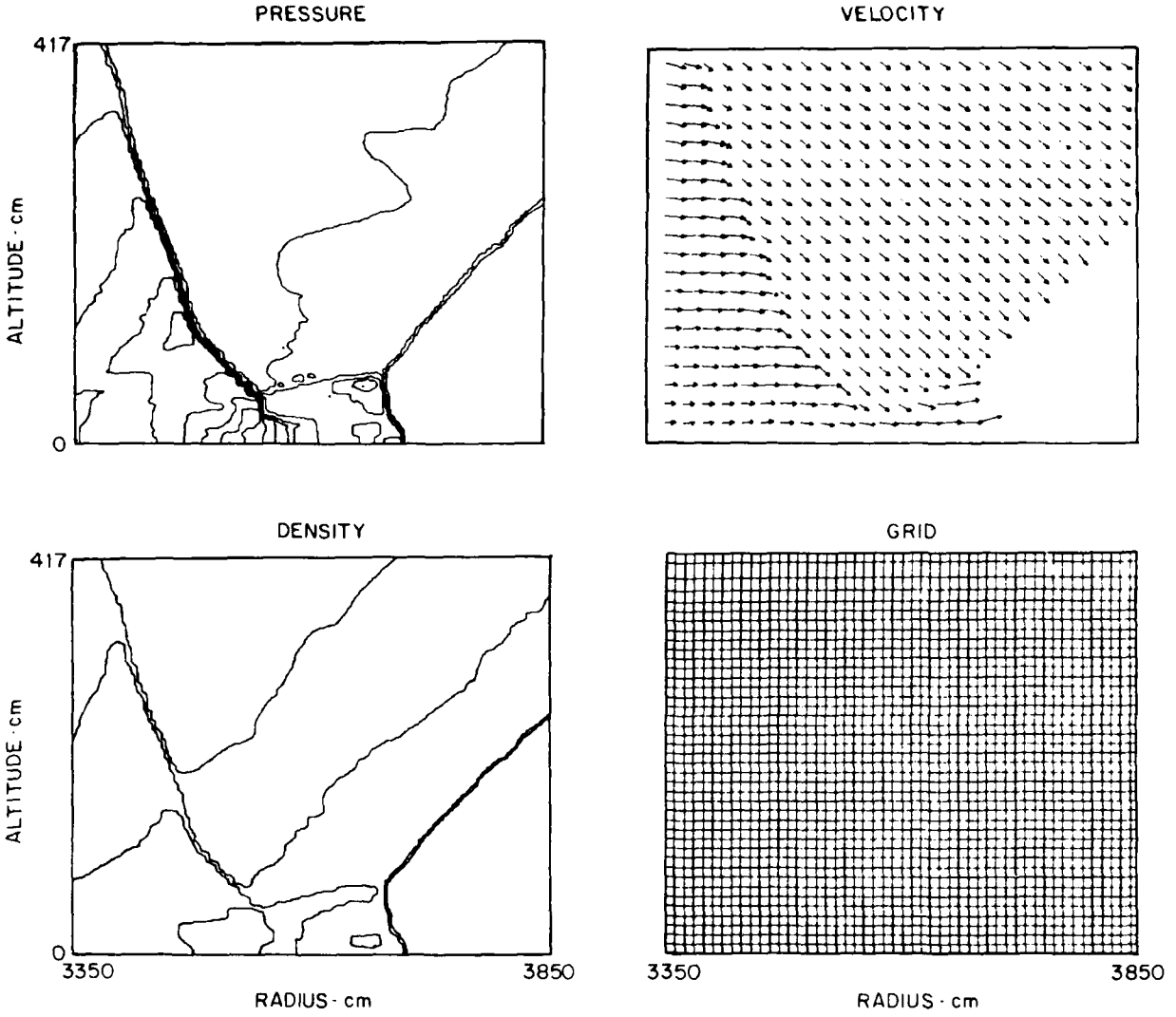
CYCLE = 6600



1 kt AT 104 ft HOB

TIME = 7.39 msec

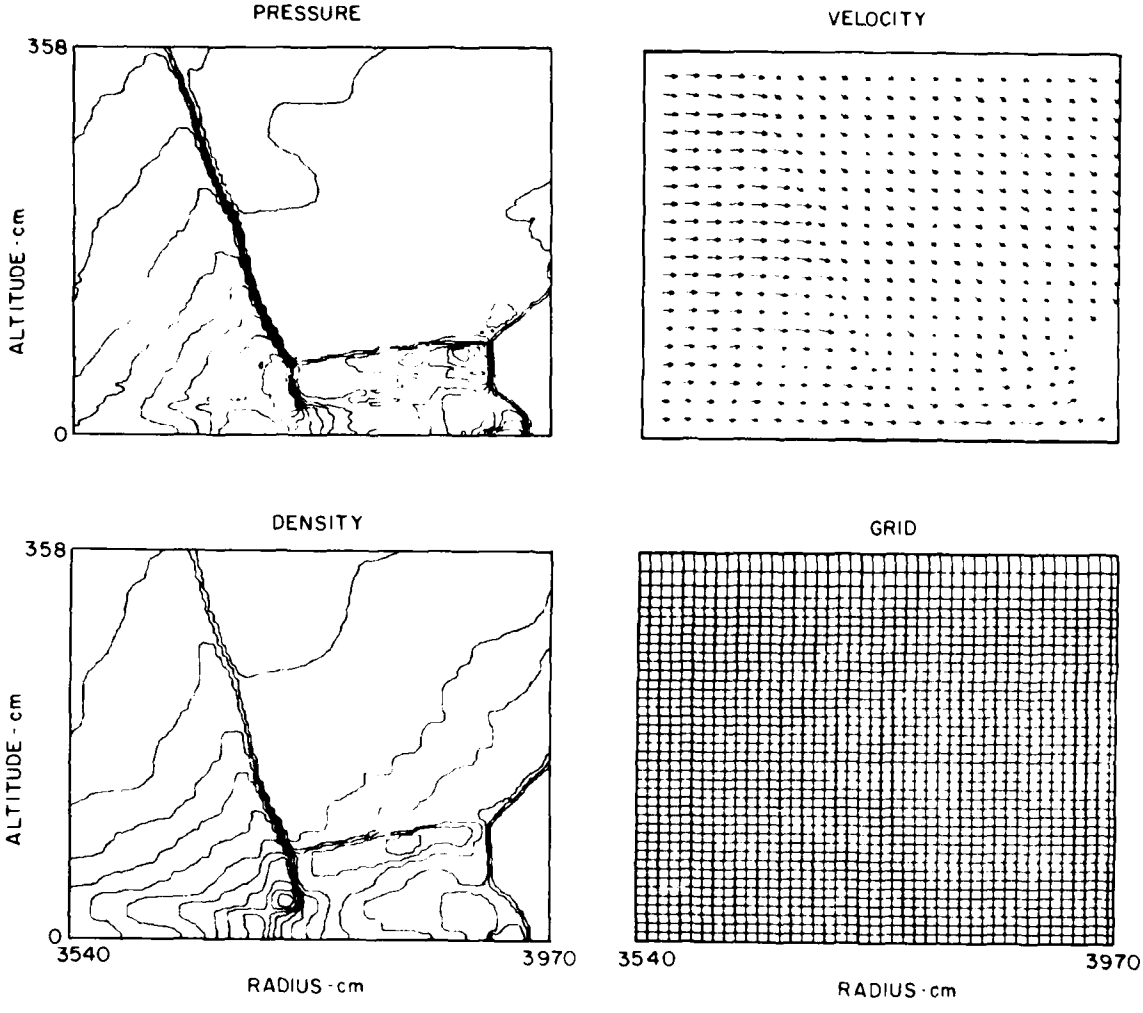
CYCLE = 6800



1 kt AT 104 ft HOB

TIME = 8.28 msec

CYCLE = 7200



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Naval Research Laboratory
Laboratory for Computational Physics
Code 4040
Washington, D.C. 20375
100CY Attn J. Boris

DEPARTMENT OF DEFENSE

ASSISTANT TO THE SECRETARY OF DEFENSE
(ATOMIC ENERGY)
WASHINGTON, DC 20301
  01CY ATTN EXECUTIVE ASSISTANT

DIRECTOR
DEFENSE COMMUNICATIONS AGENCY
WASHINGTON, DC 20305
(ADR CNWDI: ATTN CODE 240 FCR)
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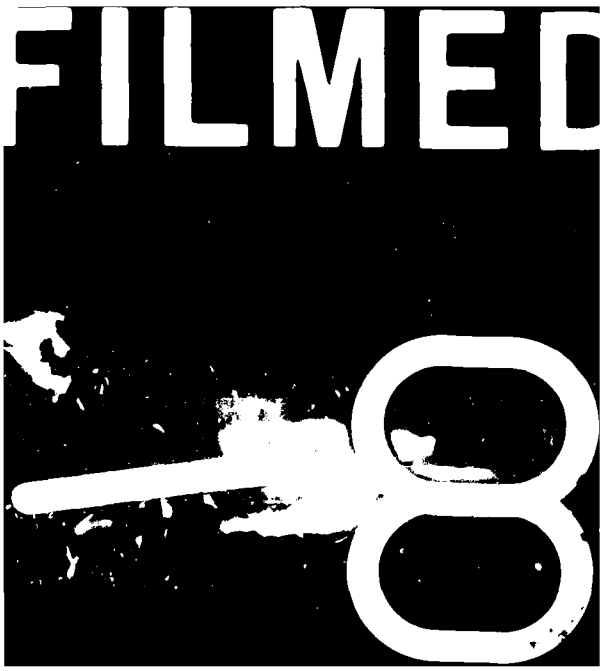
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